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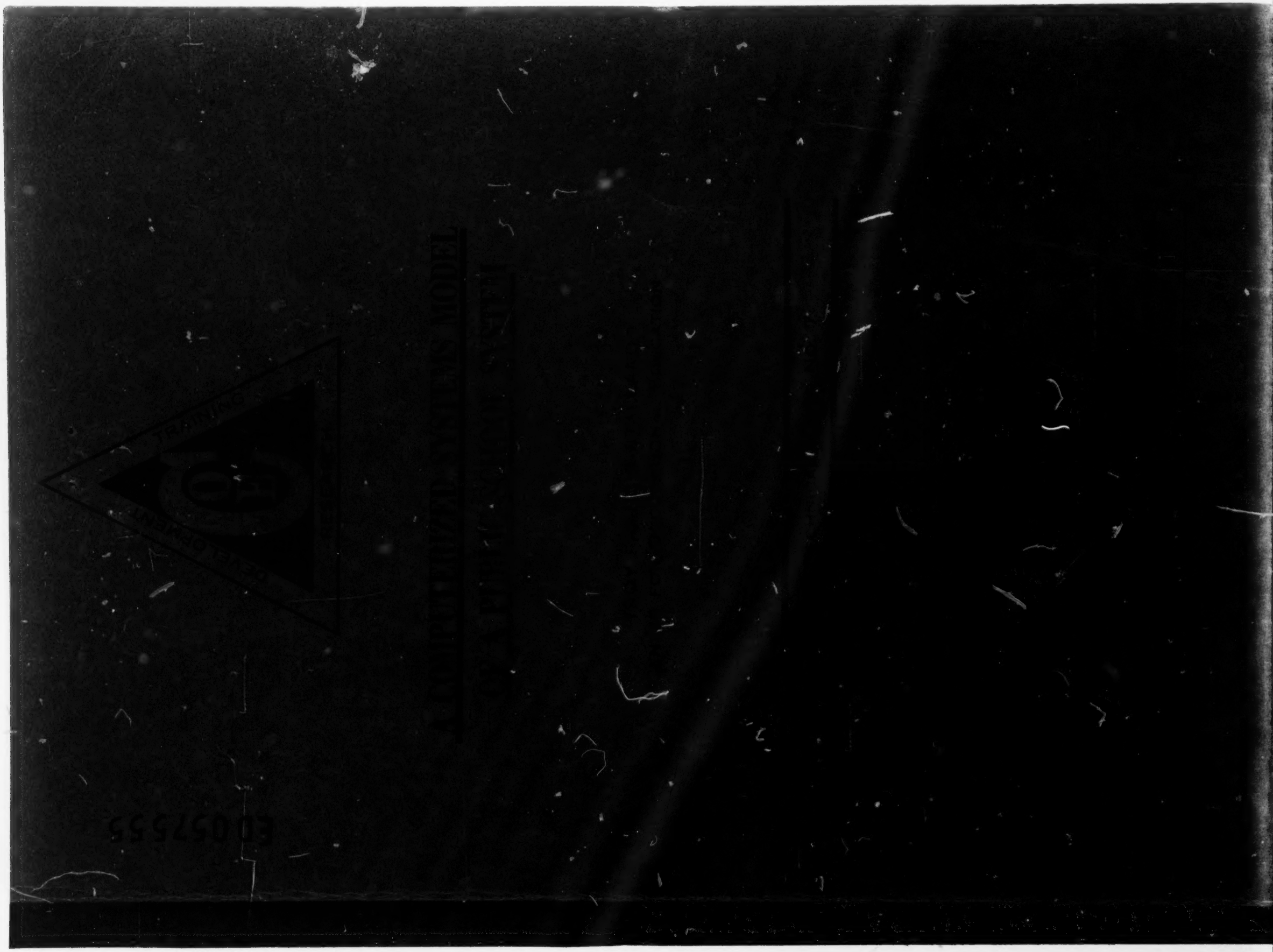
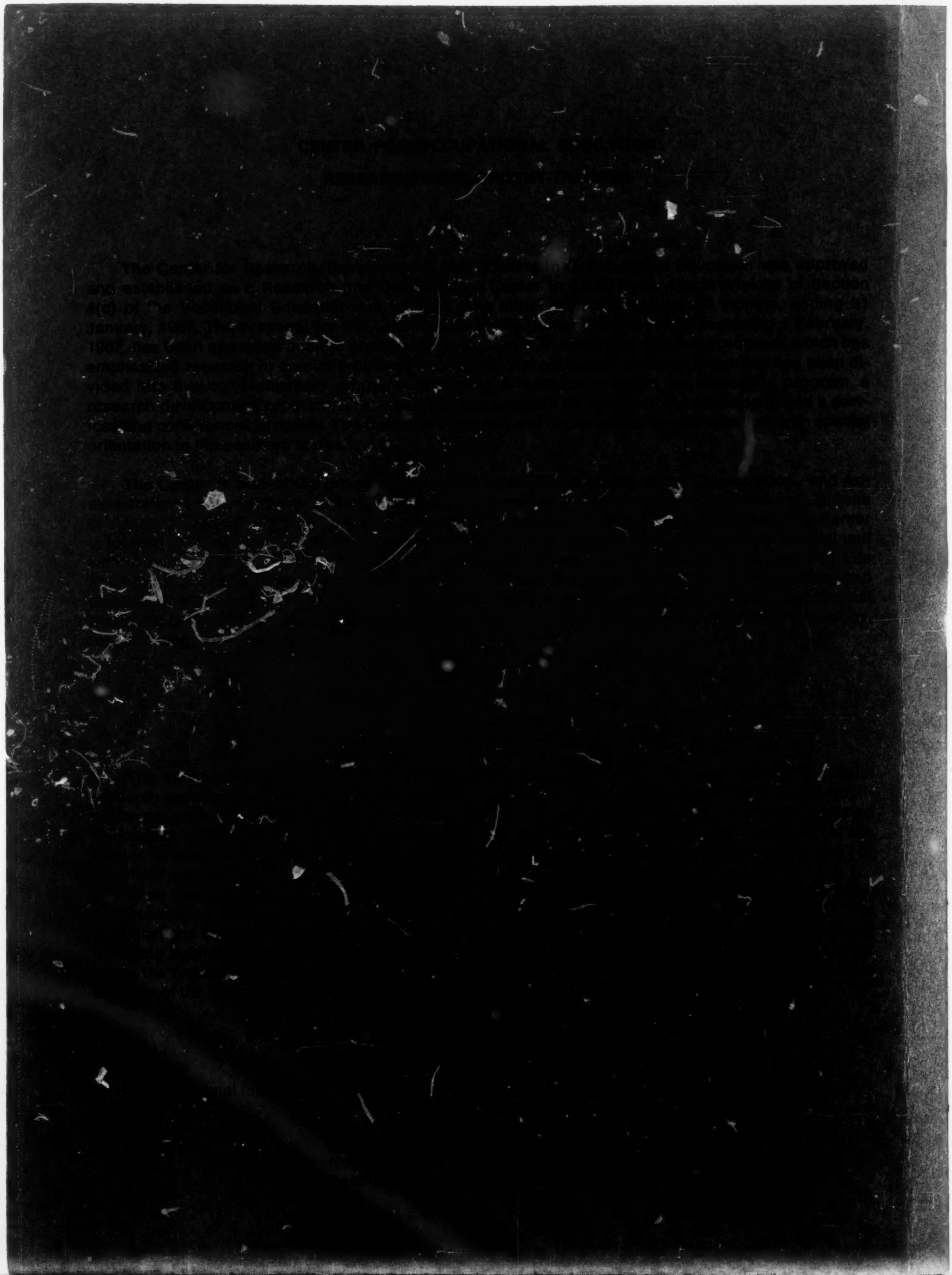
ABSTRACT

A model of the educational system in a typical public school was constructed within the theoretical framework of a general systems theory. The model is quantified and computerized so as to provide high speed simulation. Using the model developed, one can then simulate solutions to educational problems in seconds and at modest cost. The theory underlying the systems approach and the use of this approach in education are presented to provide a basic theoretical framework from which the model of the school can be examined. Then, the model is described and examples given which show how the model can be used to make decisions about allocation of resources for the system. The model is predicated on the belief that the basic components for the system (e.g., teachers, students) can be quantified. Since it is a logical model, not derived from empirical data, subjective decisions were required in the making of it. The next step will be to test the model. (JK)





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A COMPUTERIZED SYSTEMS MODEL OF A PUBLIC SCHOOL SYSTEM

Troy F. Stallard

Center for Occupational Education

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PREFACE

Although systems theory and the techniques of simulation are relatively recent innovations in scientific methodology, they have made impressive strides in the development of human knowledge. Computer simulations of extremely complex systems are now operating to help solve problems in business, industrial research and management, scientific research, and government to name only some broad categories. Yet as widely as systems theory and its techniques are used in other areas, educators have been relatively slow in putting systems theory to work in their province. In fairness to the educators, it is vastly more difficult to quantify the relationship between a teacher and a student than to quantify the relationship between an assembly line worker and the product he turns out. Nevertheless, we in education must begin to turn to these new techniques and we must be willing to attempt, at least, the quantification of certain basic relationships in the educational environment.

This report represents the completion of a task which many would have thought impossible, the specification and quantification of the basic relationships in a public school system. The computer simulation of the operation of the school system is dependent upon the ability to quantify these relationships. There may be many arguments about the quantification of the components in the system, or about the specification of system relationships, for even the judgement of experts varies on these subjects. However, there can be no doubt but that this report has paved new ground in education and has brought us one step closer to taking advantage of a new scientific tool.

The Center extends its appreciation to Troy Stallard for completing the report and to the following persons who provided professional reviews:

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John K. Koster
Director

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INTRODUCTION

The Purpose of the Study

The primary objective of this study is to construct an adequate model of the educational system in a typical public school within the theoretical framework of general systems theory. The model is quantified and computerized so as to provide high speed simulation. Using the model developed, one can then computer simulate solutions to educational problems in seconds and at modest cost.

Obviously, the educational system is a large and complex system and few facts about the system are known with complete certainty. Therefore, the model presented is necessarily an *a priori* type of model. That is, it is a logical model, not derived from empirical data. Since this is the case, subjective decisions were often required throughout the process of building the model. These decisions, whenever possible, were grounded within the context of educational research literature, and the advice of outside educational experts. In its final form, the model presents an explicit and thereby testable theory of public education. Since few explicit theories of education presently exist, it is felt that this accomplishment, in itself, has some merit.

The format followed in this presentation parallels the general outline of an actual process of analyzing a school system. After some degree of understanding of the concept of "model" and "simulation" is achieved, the rationale and the procedure phase of systems analysis is discussed. A literature investigation is presented to identify the major goals of education, and to locate important variables that exist in any school system. Later, a model based on findings in the educational literature is developed. Finally, implications of the model are tested to demonstrate some face validity for the final form of the model. These, then, are the major divisions of this text and each will be discussed separately in the above order.

Methodological Note

The usage of systems analysis occurs in many different disciplines; and because they have differing content, the methodology of investigation also differs. The physical sciences have their subject matter in a form that allows precise denotation and measurement. The analysis of an electrical circuit or a data processing system is relatively well defined. There are only a limited number of factors operating and one can usually determine the most efficient of a number of alternative ways of achieving the same purpose. However, the subject matter of the social and behavioral sciences is often nebulously defined because of the intrinsic complexity of the phenomena being studied. In such situations one is often forced to make assumptions. Moreover, the systems analyst, when dealing with these less understood systems, may employ some assumptions questionable to many other researchers. Indeed,

many persons criticize the behavioral systems analyst because he is unable to empirically demonstrate the validity of some of his assumptions. The systems analyst's reply to this attack is that the model which he constructs should not be judged on its assumptions but on the pragmatic criterion of predictability or usefulness of his model. The essential test is the model's ability to do what it was constructed to do.

Herman Affel (1964) attempted to explain what the systems analyst really tries to do in the unstructured situations that often occur in industry. He concluded that these analysts are undertaking almost superhuman tasks. They must make decisions based on subjective data at nearly every point in their analysis. They define the problem determine the goals of the system, and postulate relationships among elements in the system, while often no empirical guidelines exist to assist these men in making their decisions.

Suppose a firm wishes to have a systems analyst build a model that will generate implications for any of several alternative courses of action that management might take. That is, management desires to know which course of action is most efficient or least expensive depending on the firm's goals. The systems analyst must conceptualize and postulate functions between each of the courses of action and possible results. If data is available to help in specifying these functions, this certainly will be utilized by the systems analyst. In fact, being quite interdisciplinary, he usually accepts any kind of information as having some potential value. Nevertheless, if no data is to be found, he must still specify the form of the relationships; and to do this he must make assumptions.

Clearly, it follows that whenever the system to be analyzed is large, complex, and vague, then the analysis of one person may differ from the analysis of another person. Everything is directly deducible from the manner in which the analyst conceptualized the goals and the assumptions he made. Again, however, it is important to note that the models he constructs are to be judged only on the model's usefulness.

Most persons feel that a systems analysis will provide the ideal in efficiency for all aspects of the system. The systems approach has never been offered as the optimal solution to all problems. Yet, the users of systems techniques do feel that they can increase the efficiency or the degree of understanding of a system to some degree. They also contend that this approach usually provides better information than other methods of analysis.

THEORY, MODELS, AND SYSTEMS

The Need for Explicit Theory

> The empiricist's rebellion against the speculative era which led to the discounting of all theory and the devotion of most energy to fact finding and the improvement of verification techniques is past. There is recognition that theory can be other than mere speculation and what is more important, that it is practical ... Theory whether prescriptive or descriptive is practical. Prescriptive theory results in ends or gives direction to practice. Descriptive theory results in means or gives control to bring about the kind of practice wanted. (Maccia et al., 1963, p. i).

The authors of the above quotation offer an example of the practicality of theory. They contend that successful teaching practice is a significant factor in the development of our society; and since such teaching practices result from adequate theory about the phenomena the teacher must deal with behavior in the school setting--an adequate educational theory is needed. Often such theory exists, but only implicitly. As a result of experiences, the teacher develops personal ideas about education that seem successful to him in his practice. However, unless such ideas are made explicit and available for transmission within the teacher education process, the future teacher can only be sent forth to gain experience with the hope that his teaching practice will become successful as his ideas about education become more adequate.

It is difficult to conceive of any individual, regardless of occupational field, who has absolutely no idea of how the phenomena with which he is working operate. Thus, the worker does have a theory; even though it may be implicit and nebulous. There is a difference, however, between adequate and inadequate theory.

Definition of the Model

Melvin H. Marx (1963, p. v) has identified some important shifts in theoretical thinking in the last ten years. He found a new emphasis in a form of theory construction not fully utilized by the traditional theorists, e.g.,

> There has been a drastic decline in interest in the highly formalized theory, particularly of the Hullian hypothetico-deductive variety ... (these) retreats from (formal) theory have been matched, on the positive side, by certain upsurges toward different types of theoretical developments ... Most spectacular has been the ad-

> vance of the model, particularly the mathematical-type model.

Indeed, it is true that many contemporary theorists are becoming model builders. Nearly everyone is constructing a model of this or that phenomena. There are models describing neural activity and urbanization. There are models of nuclear fission. There are even models of modeling. The increasing literatures of nearly all sciences on mathematical model building support the idea that models have been quite successful in developing adequate theory.

While for some the term "model" has been so widely used that it has lost all semblance of meaning (Lachman, 1963), most writers describing model construction categorize the different purposes, types, uses, or functions that models exhibit, e.g., mechanical models, analog models, iconic models, mathematical models, representational models, dynamic models, true models, symbolic models, and so forth. From these categorizations general definitions can be deduced. Harold Chestnut of the General Electric Company has defined model as a "qualitative or quantitative representation of a process or endeavor that shows the effects of those factors which are significant for the purposes being considered" (Chestnut, 1965, p. 108). Marx (1963, p. 14) said, "A model is any conceptual analogue, generally of a physical or mathematical nature, which is used to suggest empirical research." Alphonse Chapanis (1963) stated simply and forcefully that models are analogies.

For purposes of definition, let the word "model" represent a set of abstract relationships that are analogous to relationships we perceive or conceive to be of the real world. Modeling is the process of making models. While the model may not be analogous to the real phenomena in every aspect, it should still describe the important characteristics and properties of the phenomena.

There are many types of models. M. D. Mesarovic (1960) purports that models are either (1) descriptive, quantitative, iconic, pictoral, and approximate in nature or (2) mathematic, exact, quantitative, and precise in nature. Roy Lachman (1963, p. 81) indirectly supported this dichotomy by stating:

> In the language used to talk about a theory, the term model may refer directly to a mathematical calculus or to a system of relationships from some other source such as electronic computers, the classical laws of motion, the laws of conditioning, etc.

In adopting Mesarovic's classifications of models, two levels of complexity are obvious. The first category refers to verbal or representative description. For instance, a model could be a woman wearing a new fashion, a physical device showing the structure of the oxygen atom, or an individual's conceptualization of the decision-making process of a corporation. This type of model will be termed "model I." The second category goes deeper and insists the modeler add operational

functionality to description. The phenomena is not merely described as in the first instance, but it is described precisely and mathematically; it is a dynamic, working model. This second type of model is called "model II."

The Relationship Between Theory and Model

What then is the fundamental difference between theory and model? Many persons say there is no difference. For example, Simon contends "contrary to general belief, there is not fundamental, 'in principle' difference between theories and analogies. All theories are analogies, and all analogies are theories" (Simon and Newell, 1965, p. 103). His term "analogies" was indicated to be synonymous with model. The position taken in this paper, however, is that there are different implications for these two words. "Model" is seen here as conveying a concept similar to theory; however, models are more sophisticated. A model is a level above theory. It is an exact statement of theory. Having formulated laws from events and theories from laws, the modeler takes the theory, implicit or explicit, and then constructs a model. (See Figure 1).

The distinction between theory and "model I" is slight. Model I refers to a representation of a pre-conceived theory. It is an analogy used for description and simplicity. Quite often writers use both of these concepts synonymously and the dividing line between them is sometimes unclear.

"Model II" is the type of concept that has become extremely popular in recent years. At this point, the phenomenon is more precisely described and more explicitly understood than in either theory or model I concepts. In fact, the phenomenon can be quantified mathematically. Naturally, innovations in methodological and computing techniques have encouraged greater usage of the model II type representation.

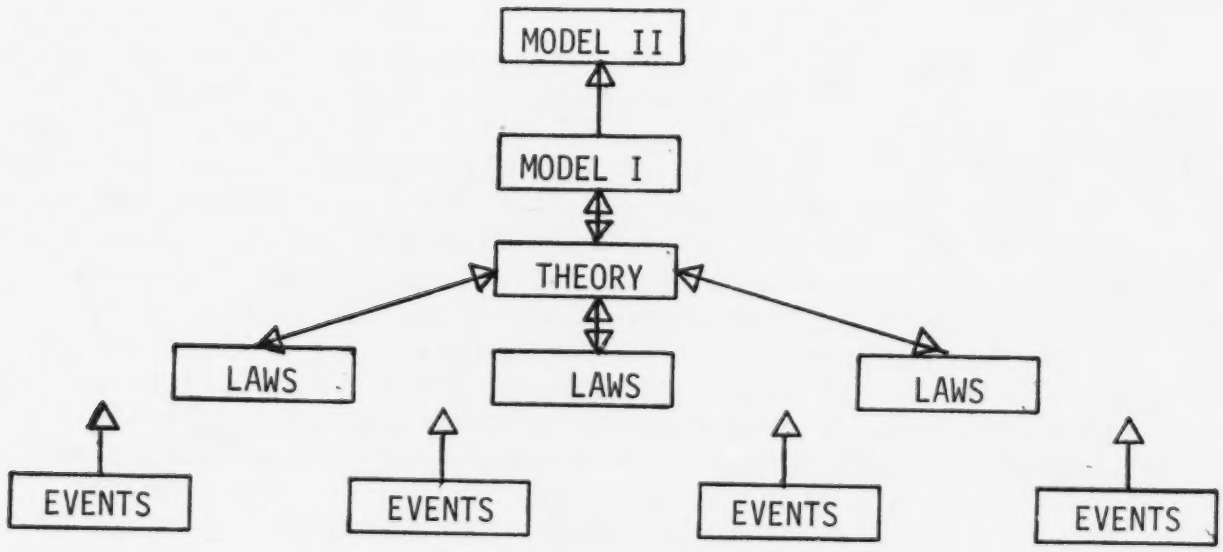

Figure 1. Relationship of model to theory

Simulation

The uses or purposes of models have been variously classified. Lachman (1963) derived four functions that models perform, while Chapanis (1963) described seven uses of models, and Chorofas (1965) noted only five such uses. Examples of some of these functions are: to augment understanding of complex systems, to learn complex skills, to help clarify new relationships, or to assist in engineering design. It is felt by this author that all these uses can be combined into two categories. First, the usage of models affords the user certain conceptual handles on reality. The user begins to think in terms of models and then he constructs a framework over a phenomenon which heretofore had evaded complete understanding. Thus, models allow users to define and structure the external world in terms which can be grasped by others more clearly than theory has often done. This purpose or usage of models has most often been demonstrated by the model I type rather than the model II types, although the latter may on occasion serve these same purposes. Second, and most important, models can be simulated. Parameter values can be fed into a model and the implications of those parameters may be deduced. Simulation of a model permits the investigator to study the effects of various systems without actually constructing and testing the phenomenon being examined. Harold Chestnut (1965, p. 107) has said:

> Thus simulation and modeling complement each other very well: the modeling represents the process or system and the simulation determines how the process or system will react to various conditions or situations it may encounter.

Simulation may require actual hardware, e.g., computer simulations; mathematical computations for a simple quantified model; the operation of a particular device, e.g., automobile driving simulation test; or the logical thinking through of the model I type representation.

Harold Guetzkov (1962) identified four purposes of the simulation technique which are: (1) the development of a body of science, (2) training, (3) teaching, and (4) systems design. Development of a body of science refers to the building of analogies which support the framework of the discipline. For example, after the atomic theory was developed, a model of the atom was constructed from the theory. Implications of this working analogy or model were tested against the real world, i.e., the real atom, to either support or refute the theory of the atom. The training purposes of simulation entail the utilization of conditions similar to the real-life setting which are, in fact, artificial and controlled. A good example of this type of simulation is the training of aircraft pilots with a machine which simulates a real aircraft in flight, but actually does not fly and is free from the possibility of a nasty training accident. Another training usage of the simulation techniques in teacher education is explained by Donald and Flowers (1966, p. 155):

> Filmed dramatizations of classroom problems, each prefaced by a verbal description of the setting in which the problem occurs, are presented to the teacher. The teacher is required to respond to the problem situation by stating what he would do in it. A feedback sequence is then presented showing the student teacher how the class may be expected to react to the teacher's method of handling the problematic situation.

The teaching usage of simulation is closely akin to the training aspect, which is to be expected since there is sometimes a fine line between training and teaching. Here, Guetzkov seems to be speaking of demonstration classroom equipment such as the human skeleton. Finally, there is the systems design usage of simulation. A mathematical model is simulated to produce overall consideration of various methods of accomplishing a desired result, and the various methods are then compared to determine the best solution, i.e., to produce the optimal system design--borrowing from the parlance of systems theory. Since it is the design usage of simulation to which this paper is directed, more complete definitions of systems terminology will be provided in the next few pages.

It is obvious that simulation and modeling as design and research techniques deviate markedly from the traditional hypothesis testing method. Instead of selecting a specific variable, hoping to control all other variables over a restricted range of values to produce an effect, the simulating method cranks out a solution, which is then tested against the real world regardless of uncontrolled factors and interactions. The model predicts results which can be compared to the true phenomenon to determine its validity (See Figure 2).

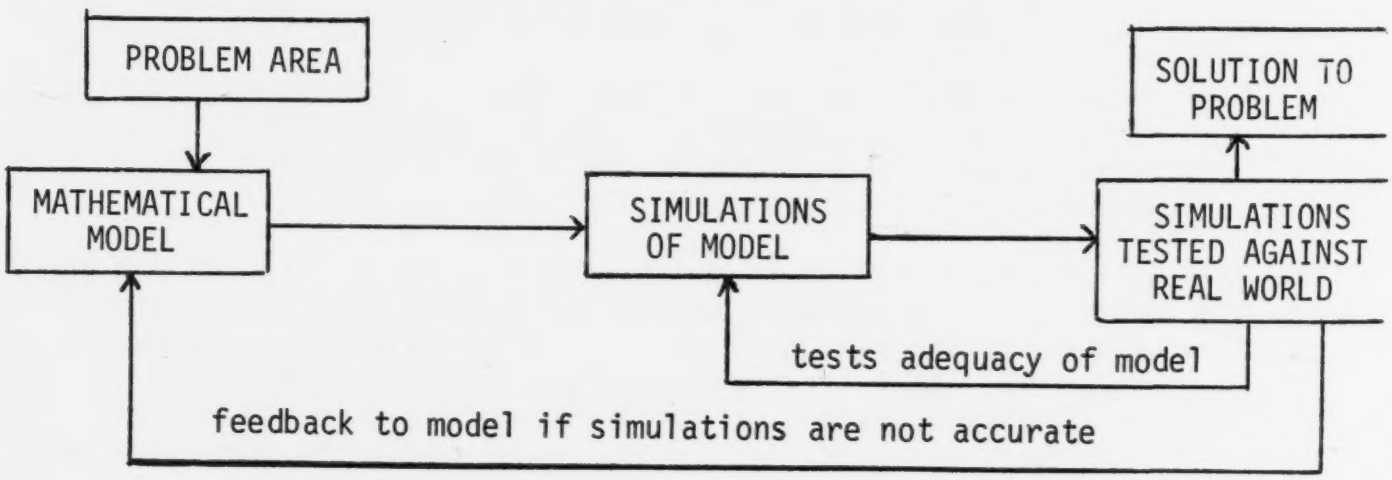

Figure 2. Process of simulation

The model, if accurate, can simulate alternative solutions as long as parameter values are fed into the model. Each of the alternatives can be tested against the real world and if, time after time, the simulated alternatives are accurate duplications of reality then the model is

assumed to be accurate and is thereafter able to generate solutions for previously unsolved problems.

Because most complex systems, companies, organizations, activities, etc. are not based on the assumptions of linearity and non-interaction of its components, this more dynamic method of investigation has become quite popular for providing solutions for these types of problem areas (Maccia et al., 1963). When one uses a hypothesis testing research design in which most variables are controlled, this excludes the possibility of an interactive relationship with a controlled variable.

Systems Theory

Historical Development

During the past two decades new analytic techniques based on model building have sprung up from the desire to understand and control the complexities of our environment. These techniques have been variously termed Operations REsearch, Systems Engineering, Mathematical Modeling, Engineering Design, or Systems Analysis and Design. According to Leonard C. Silvern (1963), one such technique, hereafter called systems analysis, had its beginning in the 1930's. At this time, RCA was utilizing systems thinking while engaged in developing television broadcasting services. Silvern also indicated that in 1950 the Rand Corporation introduced the expression "systems analysis" and the Massachusetts Institute of Technology first attempted to teach systems engineering on a formal basis. During the Second World War, the United States military leaders had used systems thinking to provide:

> ...solutions to design and development problems in complex military command and control systems that were formerly considered in the realm of human experience and intuition (O'Toole, 1965, p. 2).

The defense department has continued this policy to the present and can now aid its decision-making with the use of quantitative information about the effectiveness and costs of alternative strategies, forces, and weapon systems. These innovations are mainly a result of the influence of Charles J. Hitch, who as Assistant Secretary of Defense. Because his methods of evaluation revolutionized both the budgetary and strategic thinking of the Pentagon, he was recently honored by Life Magazine (1967) as one of the most prominent intellectuals in the country. In 1950, Ludwig von Bertalanffy (1950) wrote some articles in which he proposed a discipline called "General Systems Theory." He found that in many fields of research certain trends contained universal principles which applied to any system. He intended his logico-mathematical discipline to become a part of all sciences.

About this same time, large industries in the United States seized

the major concepts of systems thinking and accepted them as valid methods for solving complex organizational problems. It seems that this type of methodology applies to the modification of existing systems and the production of new systems, regardless of occupational field. A literature survey of all systems analysis work in industry would be a tremendous undertaking with little contribution to the understanding of this thesis; therefore, only a short suggested reading list will be offered (American Management Association, 1965; Barish, 1951; Eckman, 1961; Ellis et al., 1962; Goode and Machel, 1959; Hall, 1962; Optner, 1960; Optner, 1965; Williams, 1961; Young, 1966).

Systems theory has also been found useful in simulating politics (Easton, 1965; Scott, 1966), in modeling the person (Blum, 1961; Chin, 1961), or more generally, in both the social sciences and the behavioral sciences (Beshers, 1965; Borko, 1962; Gagne, 1962; Gwen, 1961; McFarland, 1965; Hoggatt and Balderson, 1963; Luce et al., 1965). Since 1960, nearly all accredited Departments of Engineering in the colleges and universities of this country operate graduate level courses in systems engineering. In fact, some departments have undergraduate courses or even separate systems theory from the classical divisions of engineering (Silvern, 1963). All persons involved in the area seem to agree that systems analysis has a practically unlimited future. The trends of a strong new discipline have been outlined above. It is now quite clear that the development of our culture is definitely being influenced by systems thinking.

Although it is important to be aware of the historical development of systems theory, the actual concepts and methods are the concern of this section. Questions such as how does one system analyze, what is a system, which systems are capable of being analyzed or what steps are necessary must be answered.

Definition of a System

The word "system" has been defined in many ways. Almost anyone having anything to say about systems analysis has his own personal and separate definition. Even a systems model (Figure 3) has been developed for the clarification of the definition of a "system" (Silvern, 1965). This semantic problem is further complicated by the use of identical terms by members of differing professions. Nevertheless, across all these definitions there exist common general characteristics. A system is usually referred to as the structure or organization of an orderly whole, and the working together of all the elements (parts, entities, components, or variables) in the unit to produce some outcome. Donald and Flowers (1966, p. 149) stated that "a system is a coordinated network of entities, organized for the optimal achievement of a goal." Mathematically stated, a system is $Y = f(x)$, where f is an operator (Fox, 1965).

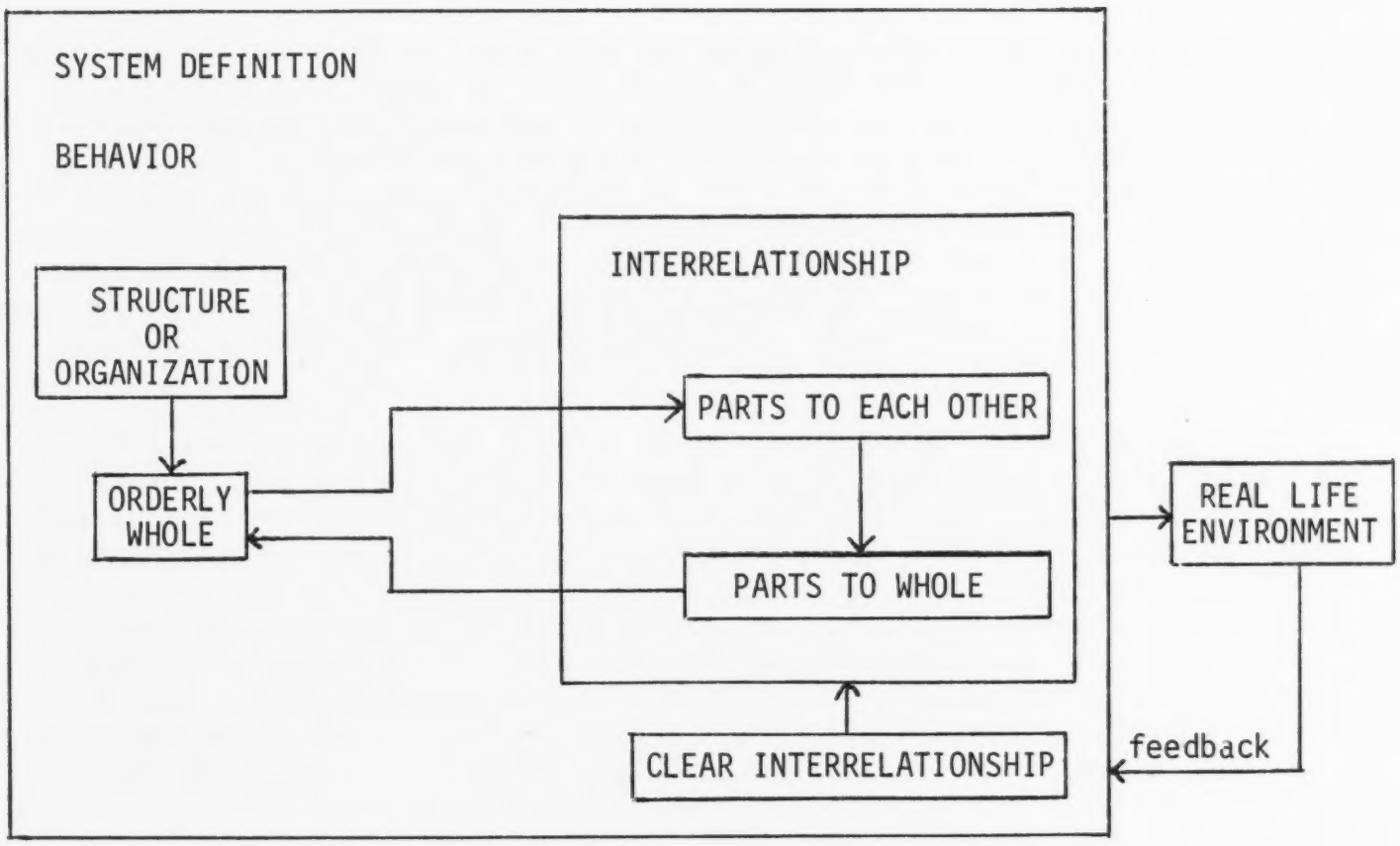

Figure 3. Flow graph of system definition

A more practical definition of systems analysis (SA) was suggested by J. A. Kersha and R. N. McKean (1959) of the Rand Corporation. SA, they purport, is the comparison of alternative means of carrying out some functions when those means are rather complicated and comprise a number of interrelated elements. The word system implies the complex nature of the alternatives being compared. Often the aim is to find the best use of one's resources, and the purpose of comparing one system to another is to show which system is better in terms of maximizing resource allocations. Usually, systems are compared in a way that is relevant to a choice between them and thus helps one to decide on the better one. One of the systems will ordinarily be an existing model (real system) while the other will be a simulation of that system with introduced changes.

Theoretical Underpinnings of Systems Analysis

An analysis of the basic tenets of SA should be conducted because the validity of this innovative technique rests, in part, on the merits of its rationale.

To begin with, there are two philosophies about the whole, i.e., the orderly unit. One philosophy insists that the thinker begin with the simple parts, understand them, and then integrate them into a unified whole. The opposite philosophy maintains that one must begin with the concept of the whole, and then identify the elements (Churchman,

1965). The systems analyst adopts the second philosophy. He looks at the entire system in relation to the purposes of that system, selects components which he feels important to the purposes, and specifies their relationships to each other. Thus, SA is actually a way of looking at the real world, a frame of reference which structures the analyst's perception. In fact, it has been suggested that students learn to view everyday problems using the systems approach (Fattu, 1960). That is to say, students are to be taught to think in systems theory and thereby solve real world problems.

The systems approach is based upon a number of premises. From a review of the literature, the following tenets have been deduced. Although this list may not be all inclusive, the major tenets are presented here.

1. The idea of change is basic. The present is merely an integrated result of the past and is a foundation for the future (Chestnut, 1965, p. 11). All systems are in constant change, and it is reasonable to look at the changing process from input to output (goals). The nature of change and determination of which changes are most effective for a system are problems which the analyst must solve.

2. There are alternative ways of accomplishing objectives. Systems engineering or analysis selects the best of a number of alternative methods of meeting the aims of the system; therefore, a belief that there are multiple courses of action is a prerequisite to this type of thinking (Chestnut, 1965, p. 11).

3. Each system has its own environment and is in fact a subsystem of some broader system (Chestnut, 1964, p. 12). Each set of related variables can be thought of as a system having inputs from its environment and producing an output which is essentially an aspect of some other system. A system exists at any conceptual level desired. No matter what goal is specified, a system can be visualized which has a number of subgoals. These must be achieved to produce the final goals and may in turn be thought of as having systems to satisfy them, and so on ad infinitum.

4. A phenomenon is understood only when it has been expressed as a formal mechanistic, quantitative model (Dorfman, 1960). Although many scientists would not hesitate to argue with this position, it must be admitted that the phenomenon would necessarily be better understood if it were expressed quantitatively.

5. All phenomena within the purview of science can be so expressed with persistence and ingenuity (Dorfman, 1960). It may take years of conceptualizing to express the systems framework for a large, intricate system, and even longer for the quantification of the system; however, any system can be solved with enough time, money, and ability.

6. The validity of computational and experimental techniques is essential. According to Chestnut (1965, p. 12):

> Implicit in the concept of systems engineering is the idea that initially it may be cheaper and quicker to calculate or measure a model or simulation of a system or part thereof than it is to build and try out the actual system. Such computational and experimental methods are employed in a complementary fashion to estimate, then to verify, those portions of the system which are significant and/or for which there is reasonable doubt.

It is therefore necessary to assume that the validity of the systems approach rests on the validity of the computational and experimental techniques which it uses. SA relies mainly on mathematical equations expressing relationships, general statistics for measuring effects, and on computerization for simulating the model. However, in determining a variable's effect, the researcher is not limited to any particular experimental design. The experimental design may change from variable to variable, but it is the responsibility of the analyst to select a valid design and the accuracy of his model rests upon his choice.

7. From a systems model logical and useful recommendations for action can be made (Dorfman, 1960). Here is the idea that an accurate model does simulate reality and will act as does the real phenomenon. More abstractly, the world is deterministic and one can recreate reasonable facsimilies which will perform nearly the same as the real thing--only quicker and cheaper.

Process of Systems Analysis

Having examined the basic rationale of the systems approach, it is now appropriate to look at the methodological aspects. However, since systems work has its own jargon, it is advisable to clarify a few preatory concepts and discuss some basic definitions to establish a common language.

A system has been defined as a coordinated network of variables organized for the optimal achievement of a goal. Thus, it is imperative that the goals of a system be carefully formulated. Often the goals are not explicit or even the stated goals are actually not the true aims of the system. Sometimes a major portion of the analyst's task may be to identify the goals which are vague and implicit.

Also, a system has certain properties implied by the words "coordinated network" in the above definition. Dynamic interrelationships, interactions, operations, and processes are all involved in a system so that changes in one variable produce changes in other variables. Such changes or events take place between the input of energy into the system and the output or achievement of a goal. This is the black box idea, in which there are inputs entering the system (black box) which are operated on to produce an output (See Figure 4).

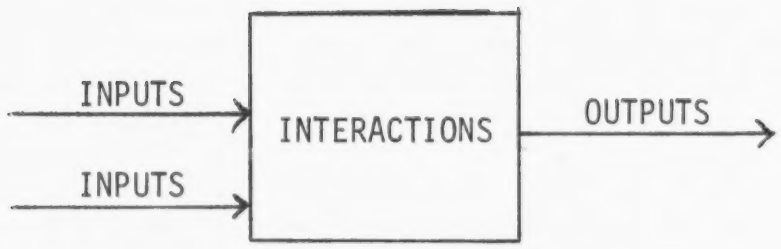

Figure 4. The black box concept

Systems analysis is concerned with the clarification of the variable relationships between input and output. Identification, specfication, and measurement of the relationships between the system variables, inputs, and outputs relevant to the ultimate goal is a job for the systems analyst. Given sufficient information about certain variables and their relationships to other factors, he is able to predict the value of those factors which were previously unknown. With knowledge of the form, i.e., the mathematical form of the relationships between variables in the system, one can determine what outputs will be generated by particular combinations of input values. Thus, it is possible to show the alternative means of producing desired outputs, a process termed "systems design" by McMillian and Gonzales (1965). Systems design is the comparison of alternative means of producing some output or outcome in a way that a design can be located in which the processes, operations, etc., will be as efficient as possible in a given situation.

The technique of simulation, which has been discussed previously, is useful in either systems analysis or systems design. To clarify the systems theory's usage of simulation, the concept will be presented again from the systems viewpoint. Perhaps it is easiest to conceive of systems simulation as the prediction of one system by another system. To further explain, let one system "a" be a real system, i.e., reality; and let another system "b" approximate within prescribed limits the real system "a." Both systems have laws and relationships like any other system. The degree to which "a" can be predicted by "b" is the degree to which it is simulated by "b." The second system, "b," is then referred to as a model of the real system and manipulation of the model is analogous to manipulation of the phenomenon itself. Simulation involves subjecting models to various inputs or component values in a way that will produce the same results as would the real system. These are modifications of the ideas of C. W. Churchman (1957).

Model construction of the model II type is a principal endeavor in systems analysis. Optimal utilization of the model through simulation is a systems design problem.

Several other concepts are useful in systems thinking. The word "parameter" refers to a variable inside a particular system whose value is determined outside that system (Magrabi, 1965). Its value is placed in the system by sources outside and it remains constant during simulation. Hence, a parameter can take on any value the analyst may wish.

A subsystem is an orderly whole incorporated in a larger, more complex, orderly whole. It has the same properties as does the larger system. Any complex system can be described by a collection of subsystems. Once again, the subsystem can be devised at any conceptual level desired.

Most authors in this area specify a discrete number of steps to be taken when one performs the analysis of a system (Chorfas, 1965; Dorfman, 1960; Thomas, 1965; Van Dusseldorp, 1967). Because the system may vary from situation to situation, it is impossible to formulate a specific set of rules to use on all systems. At least, this is true in the present stage of the development of the systems approach. O'Toole (1963, p. 13) said, "The analysis of systems is really too young a field to have matured any considerable body of accepted doctrine." One must decide in each case what the best procedure is. Different systems may require slightly different types of analysis. Nevertheless, the most often mentioned steps are listed and described below.

1. Conceptual specification. The systems analyst is faced with a creative task. He must visualize and abstractly describe the entire system. The major criteria for making any decision rest on the meaningulness or usefulness of the selected course of action. A secondary criterion deals with the precision of the model. The less coarse or general the conceptual model, the more precise will be the prediction of the real system. Thus, initially the analyst must decide how trenchant he desires his model to be. Using these standards, the thinker conceives the system. This process may be time-consuming and sporadic, since the scheduling of ideas is almost impossible. James Beshers (1965) indicated that sometimes years are spent in conceptualizations of a large scale system before any kind of mathematical work is begun. This is the stage in which the skills of the analyst are utilized to construct a valid or invalid model. This step is a great deal like the "define the problem" step in a hypothesis testing format and it demands intuition, creativity, and a well-developed skill in imaginative thinking.

a. Identification of the goals. Each system, by definition, has goals. The analyst must correctly identify the goals and be able to state them in exact terms. Many systems have very obscure goals and often the larger a system is, the more vague the goals are. It seems that goals are interpreted variously if the system is complex, i.e., secondary or subsystem goals, internal aims, extraneous variables are easily confuesed with ultimate goals. In order to build an accurate model the goals must be identified.

b. Definition of the output. To obtain the output of a system, one asks what the system does to produce or achieve the stated goals, and again, the output must be explicitly stated.

c. Determination of the input. Input is concerned with what goes into the system or what is operated upon to produce the output. Specification of input is often stated in terms of resources or manpower.

d. Identification of the relationships between input and

output. Determination of the important factors involved in changing input to output is important. More precisely, this is the identification of the relevant system parameters and their interrelationships. Upon completion of this stage of conceptualization, a conceptual model is said to have been developed.

2. Quantification of the model. The relationship between any two variables in the system must be mathematically determined. In other words, the analyst must know what the effect of any variable is upon any other variable, and he must know it exactly, i.e., in the form of a mathematical relationship between them. At this point the conceptual model becomes a quantitative model. If the number of variables is so great that it becomes onerous or difficult to remember all the relationships, it is often advantageous to enlist a computer to handle this memory problem. By stating the mathematical form of the relationship, the variables and their effects can be written as a computer program. Such a computer simulation model of the real system described by the model will perform, in a matter of seconds, as the real system would perform over a period of days, months, or even years. This model is explicit and can be read as data processing cards or mathematical equations.

If application of the model to a somewhat different situation with similar characteristics is desired, it is possible to change some appropriate system parameter, and then process the program again. By varying the parameter's values, one can continue to run simulations of the real world until the best alternative values of the parameters can be located. Computerization is also important in identifying variables or relationships which may have gone unnoticed. This is possible by developing a model and computer simulating with different variable combinations until the model performs as it should. Essentially, this is a process of development by iteration.

3. Testing of the model. The model is tested against the real system to see if it performs as it should. As mentioned above, this process can take place on a computer if there are a large number of variables. The simulated data must approximate the real data (data concerning the real world phenomenon) within predetermined confidence limits. This is a validation process.

a. If the model does not simulate reality, the analyst must return to either the conceptual or quantification stage to locate the source of his error. Once the error has been located, he can begin again at that point.

b. If the model does simulate reality, then very often cost accounting procedures will be attached to the simulation model. A dollars and cents evaluation is applied to the inputs and outputs and system variables. This procedure is almost universally accepted among systems analysts to show clearly the relative worth of particular combinations of inputs and/or parameter values. It is then possible to make comparisons of alternative systems using a monetary criteria. It

is relatively simple to make such cost accountings, since all that is required is the enumeration of the costs of each manipulated element in the system. This task can be done easily by any accountant and causes the systems analyst no trouble. Such accounting models will be of the most use to those interested in the optimization of allocation of resources.

4. Implementation of the model. The model is now ready to perform any systems design problem pertaining to efficiency maximization. The model processes different parameter values until an optimal solution is reached. If a monetary value is attached, the model will simulate until the best system for the least money is selected. Once the best system has been determined, it is only necessary to change the real system along the parameters indicated by the model. Thus the model will alleviate the effort, time, and money that would be involved if one attempted to modify the parameters of the real system until the optimal solution was found.

5. Updating the model. Since large systems change from time to time, it is usually necessary to change (update) the model to reflect the current status of the system. Updating involves a complete re-evaluation of the real system and the changing of any obsolete or omitted parameters of the model.

In concluding the discussion of general systems theory, a brief listing of the criteria useful for determining whether to use systems analysis or not on a particular system will be offered. Roy (1958) lists three such criteria. (1) The system must have data which can be quantified. (2) There must be an opportunity to choose from different alternative solutions. (3) There must be ways to evaluate the results. It is felt that two additional criteria should be included: (4) The system should be too large and too complex to be handled by other methods easily, and (5) The cost and time needed to build a model should be negligible in relation to the demand for the model.

EDUCATION AND SYSTEMS THEORY

Education as a System

The educational system has inputs which are operated on to produce outputs. Some of these inputs into education are students, money, and manpower. The output of the educational system is usually thought of as educated students. There also exists a large number of parts (components, entities, etc.) of the educational system, e.g., teachers, classrooms, and administrators. These parts are intricately interrelated and interwoven into an extremely complex network. And the inputs are mixed with the system parts in various ways to produce an outcome or output. That is, the systems, parts, teachers, administrators, etc., change or operate on the input, students, to produce an output.

It is also conceivable that there are smaller systems or subsystems within the supersystem of education, e.g., the instructional subsystem, the financial subsystem, or the facilities subsystem. Each of these subsystems have inputs and outputs and interrelated components. And, indeed, the subsystems have sub-subsystems and so forth.

Thus, the educational system is a complex coordinated network of inputs, components, subsystems, etc., organized to produce some outcome, i.e., educated students. This way of describing education fits perfectly the definition of a system in the sense of formal systems theory.

When one considers education as a system, then there is some justification for utilizing the systems approach in education. And, it is the contention of this paper that the educational system can be investigated and modeled with the same techniques that are used in examining an electrical system or a missile defense system.

Roy (1958) proposed three criteria that must be met by a system before a systems analysis could be undertaken. In accordance with his criteria, most analysts would agree that (1) educational data can be quantified. Today, psychological and sociological theory and technology make it possible to measure constructs, attributes, etc., that may previously have been unquantifiable. Also, (2) there are numerous opportunities in the educational system for alternative ways of solving a particular problem. Finally, (3) ways can be devised which will evaluate the results of a systems analysis. For example, the amount of learning of one group under ordinary instructional conditions may be compared with the learning of another equally intelligent group using an innovative instructional media presentation of the material. Thus, any prediction of a model concerning the results of the above situation could be compared with the actual results. In summary, the educational system seems to be compatible with all the specifications for a systems analysis.

It may be further pointed out that the educational system of today

is in a revolutionary stage. There is vast literature on this subject. Research is being conducted on all sorts of technological innovations. New ways of teaching, new teaching machines, new curricula material, and different teaching conditions are all being investigated thoroughly. It is in this type of environment that SA flourishes (Meals, 1967). Wherever there is an increased ratio of change and complexity, there is fertile ground for the systems approach. Education currently has such a status.

Since educational research has been conducted on a prodigious number of variables, one may ask what the utility of the systems approach to education actually is. It exists in that these piece-meal studies done on one or two variables at a time do not present the overall picture. Certainly, it is useful to know that decreasing the student teacher ratio may increase student performance. But, the systems analyst would ask if this (decreasing the student teacher ratio) is more important for student performance than requiring more teacher training, than getting better teachers by increasing their salaries, than introducing new audio-visual techniques, and so forth. With a systems model one could make comparisons of this sort and produce a more ideal educational system in terms of the stated objectives without going through the process of trying each method in a real school situation and then trying to judge the best alternative.

Historical Development of Educational Systems Theory

In 1959, Kershaw and McKean (1959) did a study for the Ford Foundation which was essentially a report discussing the potential of SA in relation to education. This paper was a catalyst and it initiated an increasing amoung of literature in this area. Their conclusion supported the feasibility and necessity of such an attempt.

The next year Fattu (1960) discussed some recent innovations in the social sciences that had not been, but should be, explored in educational research. Referred to explicitly are model building, simulation techniques, and SA.

The years 1961 and 1962 brought on the first attempt to utilize this approach as Bushnell and Cogswell (1961) began investigating instructional media systems. Monch (1962) maintained that only through SA could cost relationships be defined clearly. Also in 1962, a symposium was held at Sanford University where it was decided that a systems approach to education was drastically needed. James A. Thomas in a dissertation (Thomas, 1962) for his Ph.D. degree presented a model of efficiency in education. He correlated input variables from the school, e.g., size of school; and student achievements, e.g., student language fluency scores. He then tested a priori postulations by comparing the observed correlations and his previously predicted correlations.

By 1963 the literature was increasing rapidly. Donald Bushnell (1963) discussed computer simulation as a new tool for education. Leon ard Silvern (1963) published a paper entitled, Systems Engineering in

the Educational Environment. In this paper he indicated that the systems approach in education was at that time in a state of wishful thinking rather than in a state of accomplishment. However, he did provide a set of flowgraphs for explaining a number of important systems concepts, e.g., definition of a system and definition of analysis. He defined the process of systems analysis as involving an analysis of the components and the relationships and then a synthesis of those same parts into a new whole. For this process he coined a new word, "ana-synthesis."

The year 1964 brought further activity. F. Restle (1964) demonstrated how an educational problem could be analyzed mathematically through application of probability theory. He defended the position that classroom conditions, restraints imposed by the situation, and the intrinsic variability of the learning process could be taken into account mathematically. Also, he suggested that high speed computers be used in complex analysis of this sort. The Operations Research Society of America at their semi-annual meeting in the fall of 1964 listed two papers prepared on the use of SA in education (Robinson, 1964; Schroeder and Roth, 1964). Both papers emphasized the relevance of such an approach for educational problems. This same year more work was continued in instructional media systems by the Systems Development Corporation of Santa Monica, California, which was following up on Cogswell's earlier report. That year was the first of a series of reports from Systems Development Corporation on educational systems analysis which now number about twenty. Another publication (Vandermeer, 1964) discussed a number of studies ranging from the effect of a specific audio-visual medium to the influence of a number of media in an educational system. He suggested that SA could be applied appropriately to the total school environment.

The following year Audio-Visual Instruction produced an entire issue devoted to the systems approach. In this issue (A. V. Instruction, 1965) contributors such as Churchman, Bushnell, and Silvern discussed the usage of systems analysis in all aspects of education. This same year J. A. Thomas (1965) claimed that education was an industry and should be treated as such, using the industrial tools. He noted:

> The key to coping with commercial pressures in any organization lies in the development of effective decision making procedures which include definition of objectives, the generation of alternatives for reaching objectives, and selection and implementation of one or more alternatives ... Systems analysis partially fulfills this need. (Thomas, 1965, p. 203)

In another study Judy (1965) reported a computerized model developed at the University of Toronto, Canada, which provided school administrators with information for decision making in areas of staff, space, materials, and money. His model simulated a number of alternative uses of school resources and showed the resulting values of each alternative. Harry Silberman and L. F. Corter (1965) stated emphatically that formal hypothesis testing studies are by themselves inade-

quate; they have a place, but they must be integrated into a larger framework of the engineering approach. Finally, John Forbes (1965) described a computer simulation gaming model in which academic planning for a hypothetical institution of higher learning was expected to carry over into real-life decision making.

In 1966 the Systems Development Corporation completed a design for a Continuous Progress School (Cogswell et al., 1966) and found that there are two ways of using SA in education; first, to facilitate improvement of present instructional and educational planning systems, and secondly, to explore the feasibility of proposed school organization. Also Donald and Flowers (1966) attempted to explain to the Canadian educators the major concepts and uses of SA in education.

E. Exton (1967) reported that the United States Office of Education is using SA in a number of problem areas in education. Blaschke (1967) indicated that the Department of Defense has been behind all the recent innovations in the area of educational technology, and he commented that unless local concerns begin utilizing some of these newer methods, especially SA, the educational program may become too centralized. R. A. Van Dusseldorp (1967) discussed both the relevance of SA for education and the steps involved in undertaking this type of analysis. H. A. Bern (1967) published a paper whose title reflects the current status of SA in education: "Wanted: Educational Engineers." However, the most noteworthy event of 1967 was a symposium on "Operation Analysis of Education" held in Washington, D. C., on November 21-22. This symposium was sponsored by the U.S.O.E. and attracted some of the leading spokesmen in the area. Also, the U.S.O.E. provided a bibliographic guide (U.S.O.E., 1967) to publications in the operations or systems analysis in the field of education, and they published their student achievement model (Mayeske, 1967).

Discussion of Three Major Investigations

It is now appropriate to examine three studies, which are the most complete and the largest of the works in this area. It is believed that a detailed account of these investigations will afford the reader a better understanding of the systems approach in education.

First, according to Exton (1967), the United States Office of Education is going to apply SA to five basic areas which are: (1) educational factors, (2) educational systems, (3) school-community systems, (4) educational technology, and (5) educational economics. From these areas, it is planned that a family of models will be developed. These models will deal with problems ranging from defining educational objectives to the actual measurement of the goals. This undertaking is the responsibility of the National Center for Educational Statistics who plan to computerize some of their models. A few models are now existent such as a community-school model for investigating the relationships of educational resources of the community, a student-teacher interaction model, a cost-benefit research model, and an

occupation requirements model. The output or goal of education for their models seems to be one of student achievement. A flowgraph representation at a very general level of the student achievement model is shown in Figure 5.

A second paper (Judy, 1965, p. 2) to be discussed begins with the basic premise:

> Educational resources are scarce and should be used efficiently. In the administration of these scarce resources, university officials deserve managerial tools as powerful and sophisticated as those available to managers in business and government.

To serve this purpose a model was developed which simulated the University of Toronto's operations over a time period of any length. Loaded into a computer, the model accepts descriptions of the university's structure and statements of the levels of activities that a university is expected to perform. With such inputs, the model simulates the optimal resource requirements of staff, space, materials, and money. Judy (1965, p. 3) goes on to say:

> With a simulation model at hand, the university decision maker can test alternatives before choosing. He is able to plan in anticipation of problems rather than respond in the face of unforeseen crisis.

Although the quantified model is restricted by the University of Toronto, they do make public the conceptual flow diagram. Also, examples of problems and their solutions are presented. Four ways of developing parameters, along with estimates of the time required to build such models, are given. However, the output of the model is in terms of staff, money, space, and materials while nothing is specified about student learning or achievement.

A third organization doing work in SA in education is the Systems Development Corporation (S.D.C.) in Santa Monica, California. This organization obtained financial support from the Educational Media Branch of the United States Office of Education for research on "New Solutions of Supplementing Instructional Media through Analysis and Simulation of School Organization" (Egbert, 1963). Since 1963, a number of technical reports and documents have been published from this work. First, a series of reports on a system analysis of the Continuous Progress Plan High School was undertaken. The Continuous Progress Plan makes extensive use of small group instruction to clarify new concepts and learning material including programmed materials which permit each student to progress at his own rate.

The first reports (Cogswell and Egbert, 1964a) were mainly descriptive and the data from a SA was used to construct an explicit descriptive model of the Continuous Progress Plan High School. This model was ini-

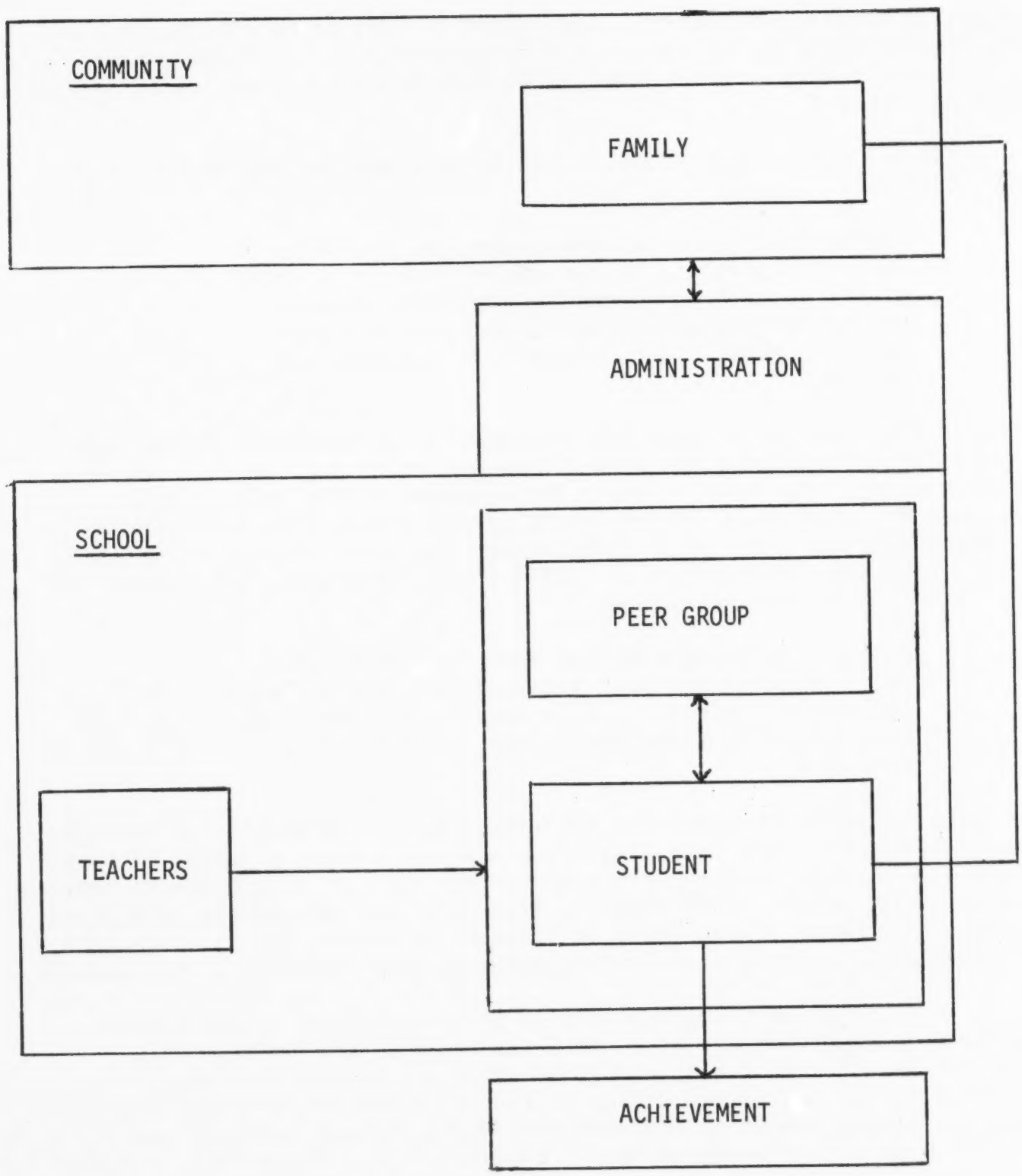

Figure 5. U.S.O.E. Flow graph of student achievement

tially in the form of flowgraphs. These reports dealt with background, overview of Continuous Progress Plan, student movement through school, course work in language, art, and speech, and academic functions of testing, scoring, and interpreting.

The second report (Cogswell and Egbert, 1964b) used the systems analysis description of the system to design a surveillance and detection system. This function is interpreted to be a vital subsystem of the Continuous Progress School and is viewed as a part of an Information Processing Center. They stated that as the name Surveillance and Detection implies the purpose of this system is, first, to detect the presence of trouble when it occurs or is imminent; second, to monitor the activities of the students; and third, to alert appropriate personnel for action. The system makes sure students do the assignments and also, it conducts periodic reviews of student performance, compares actual performance with that expected, and alerts responsible officials to any major discrepancies.

In the third report (Cogswell and Egbert, 1964c) on the Continuous Progress School, a design was presented for an Instructional Materials Center. The Center combined the functions of the library, bookstore, audio-visual center, and materials development. Such a center could be seen as playing a major role in any Continuous Progress School. At that time, no such subsystem existed; however, the S.D.C. believes, on the basis of the systems analysis, that one should have been established. During the investigation of the Continuous Progress School, an attempt was begun by S.D.C. to evaluate and plan change in school organizations. A computer simulation model (Cogswell, et al., 1965) was developed which would simulate student movement through a school system, i.e., the model would estimate the number of hours students take to complete a given course under certain conditions. For example, an experiment can be set up to determine how long it takes students to achieve a certain level of proficiency using a television instructional media. A computer, loaded with the model, would be able to approximate the same distribution of the number of hours without actually doing the experiment.

From the general attitude toward education at S.D.C., several papers were produced. O'Toole (1965b) attempted to clarify some of the systems concepts and Cogswell (1965) supported a task-oriented point of view instead of the more traditional personnel-centered one toward education. Educators should become aware of the advance of man-machine systems in education and must plan from that position and not plan entirely on the personnel staff to conduct the business of education.

In 1966, the S.D.C. published a 276 page final report on the Analysis of Instructional Systems (Cogswell et al., 1966). This was the summary of the project begun in 1963. The purpose of the study was to explore the uses of systems analysis and computer simulation in studying innovation in secondary schools. Eleven systems analyses were done at six schools and the results indicated (1) two uses of SA in education: analysis to improve teaching or instruction and analysis to improve school organization, (2) the recommended procedures for a systems analy-

sis consist of (a) defining the major overall problem to be solved by the system, (b) modeling the system, and (c) drawing implications from the model relative to the purposes for the system, and (3) educational computer modeling is feasible and provides the analyst with a model that is both explicit and manipulatable.

Even though the history of SA in education goes back only eight years, one can see that many persons believe that there is a great future for this method of analysis in education. Each year more people become involved in these activities and each year more reports are published about these activities.

In the future, models will be built for many types of objectives. Since computers and computer personnel are becoming more available to school systems, one day educators may order computer models to achieve their goals as they now order standardized tests. And, perhaps, community planners may also order models to study how their schools should be structured to meet the community needs.

DEVELOPMENT OF THE MODEL

Procedure

The content of this paper heretofore has been primarily concerned with two topics: the theory underlying the systems approach and the use of this approach in the field of education. A discussion of these topics was necessary to provide a basic theoretical framework from which the model of the school developed in this paper can be examined. In turning to the main concern, the format used in the construction of the school model is the same as the steps presented in the section on the process of systems analysis. Each activity will be discussed in the order of the development of the model.

Conceptualization of the Model

The School Concept

The idea of the school being a system with inputs and outputs and dynamic interactions was presented in the previous section. Naturally, the educational system may be inspected from a national, district, or an individual school level. The unit of inquiry was defined in this paper as an individual school. That is, the logical domain of investigation is considered to be a single school with its teachers, facilities, curricula, etc. This school has conceptual, as well as physical, boundaries along the perimeter of the school's property. The conceptual boundary is permeable and influences from the community may enter the system to affect the school. The school unit is limited to schools which are public and which have any or all of the grades from one to twelve, e.g., elementary, junior high, senior high, secondary, or union schools. One further restriction was imposed on the model for clarity and simplification. The school system was conceptualized without the students being a part of it. Thus, the main interest is directed at the system variables, i.e., the variables that are a part of the school unit itself. This is actually an examination of the operators on education and not the educational process proper which is concerned with how change is produced in the student. In other words, the school was modeled as being potentially able to cperate on students.

Identification of the Goals of Education

When one attempts to conceive of education as a set of outputs which are influenced by inputs and parameters, any initial questions allude to the expected value of education for society. Such questions concern the goals of the educational system, which necessarily must be identified and explicitly stated in order to properly analyze a system. It is difficult to speak of outputs without fully understanding the purpose for which these outputs exist. It is only from the perspective of the overall goals that an analysis can be made; otherwise, secondary and minor subsystem goals

and outputs may confound the analysis and allow the construction of an inaccurate model. Since a system operates to produce the achievement of some goal, identification of the goals is the first step.

A great number of books and articles have been written on the goals, aims, objectives, or purposes of the educational system. However, there are few writers on this subject who agree entirely on the goals of education. Perhaps it is because of the complexity and size of this system that the ultimate goals have been variously interpreted and are quite vague. Futhermore, when the goals are actually mentioned, they are in a rather elusive form and only seldom are they explicitly stated. It turns out to be a formidable task for any analyst to cut away the surrounding philosophical duff and formulate some explicit goals for education which are important to any school system. It was hoped that through a literature search some common, recurring themes could be identified and precisely stated. Realizing, of course, that there is no possible method of empirically determining these goals, the only way to structure the criteria of education is to make subjective decisions based on logical analysis.

Most of the goals of education were abstractly stated in some generalized form such as: a student should be educated to his fullest potential as an individual with the welfare of society in mind. Many of these general goals, upon close examination, revealed a pattern consisting of several components. These components were seen as dimensions of each student which are operated on by the educational system. From the analysis of the literature five of these component goals were identified.

One of the component goals extracted from the survey was a dimension of socialization skill. According to the United Nations Educationa, Scientific, and Cultural Organization in their published report, Economic and Social Aspects of Educational Planning (1964), education has the responsibility of restructuring the social life of the students (along with the parents and the community). Will French (1957) also stressed that the interpersonal relationships formed in the educational system will influence later social life. The School in Contemporary Society by Goslin (1965) defined socialization development as a principal objective of education. The school of today has become a place where American children develop their social behaviors. American educators contend that the teaching of social skills is an important part of the school's responsibility. Education, therefore, has as one of its main objectives the socialization of its students. Socialization is seen here as the acquisition of social skills that enable students to be more or less accepted adult members of society.

A second component goal consists of the development of a communication dimension for students. The educational system seeks to influence the behavior of the student in a number of ways. One of the most important of the desired outcomes is the development of skills of communication. One of the outstanding attributes of an educated person is his facility with the communication skills of reading, writing, listening, and speaking. The enhancement of these attributes is inevitably a vital

part of the core of any educational program. Nearly every writer on educational philosophy or theory will support the claim that the development of communicating skills is one of the important functions of the school system.

Critical thinking skill development is seen as a third goal of education. Critical thinking is concerned with quantitative reasoning, analytic thinking, or logical analysis. Robert Ennis (1962) sees critical thinking as the correct assessment of a statement and castigates the schools for lack of attention to the development of this type of student competency. Robert Harvey (1961) claimed that the central function of any school is the establishment of critical thinking facilities in every student. Carlos de Zafra (1966) was even more emphatic as he argued that the future of America depends on the quality of critical thinking skills that are developed in our schools. Helen Carpenter (1963) in a yearbook report published by the National Education Association stated that logical and critical thinking are basic to the effective functioning of individuals in today's complex and confusing world.

Fourth, the development of performance skills was identified as a major goal of education. Performance skills allow one to cope with the environment by using either himself or an instrument as a tool to do something to change the environment. Performance skills are necessary to both the golfer, who plays for relaxation and thereby a more satisfactory life, and the key punch operator whose job depends on the quality of his or her performance skills. Although performance skills are developed in areas other than vocational education (e.g., sports, typewriting, creative art), vocational education is concerned primarily with performance. Vocational education enriches the student's occupational potentiality and according to the Educational Policies Commission (1938), this is one of the purposes of education in American democracy. Wolfe (1960) explained that the greatness of a nation resides in its working personnel and therefore the greatest need of a nation is in the development of a diversity of talent. Other authors (Goslin, 1965; UNESCO, 1964) also see the allocation of individuals to positions in society as an aim of education.

The four skill dimensions of communication, socialization, performance, and critical thinking are complemented by the final construct. This construct, which will be termed cognitive openness, is really the information processing procedure or the cognitive mapping of an individual's world. Different persons process the incoming flux of information differentially. It can be observed that some persons are characterized by dogmatic or closed modes of thought, while others are extremely open to any criticism of beliefs, disagreements on issues, or new ways of looking at familiar phenomenon. Milton Rokeach (1960) wrote a report of reasearch on the nature of belief structures. He found that persons do have particular ways of thinking, regardless of content. Cognitive openness need not be dependent on any specific content; indeed, it pervades all content both to structure and to attribute meaning to a world picture, regardless of ideology. These ideas of Rokeach have been modified and expanded by D. W. Drewes in a

working paper entitled "A typology of World Views,"[1] The essential theme of this paper is that beings are characterized by the openness or closedness of their information processing modes. To clarify, each individual has a cognitive structure which attributes meaning to incoming information. It seems there is a dimension composed of styles of cognitive openness in the amount of reality testing, the reformulation of beliefs about the world, or the creativity in devising new ways of looking at the world, and this dimension has a continuum from the mind closed to these types of activity to the open mind which thrives on such modes of information processing.

It is important in the development of the model to separate the concept of cognitive openness from the concept of skill. A skilled person is one who devotes his energy to some output, an end, or an effect. It is the utilization of some fixed, pre-existing, inflexible belief or model. Model is used here as a representation of an individual's concept or belief about how the world operates, i.e., model is used here in the Model I type representation. It is a prescribed technique for handling some problem in the environment. A model used in this sense is a set of expectations or beliefs about the world, which thereby increases the probability of acceptance of input which is in accordance with the model, and decreases the probability for other less acceptable input. The model also tells the person how to process and evaluate the incoming information. Skilled persons place emphasis upon the utilization of a particular model. It is the carrying through to some end or output according to a process which the model itself dictates. Skilled becomes synonymous with the efficient usage of some objective, factual, and inflexible model.

Cognitive openness, on the other hand, emphasizes the reformulation of the belief or model itself. It is the modification of the existing model by evaluating the feedback from the use of it, and then determining new ways of using or restructuring the model. Creativity and inventiveness are two major factors involved. An open person is one who continually participates in reality or hypotheses testing. He is able to vary the model from situation to situation according to his evaluation of the situation since he is not bound to the use of a particular model for all similar situations. For example, a technologist is one who is given models to put to use. There is no stress upon the modification of the models. While a scientist is also given existing models, it is always made clear that these models can be replaced and it is important to question the basic premises underlying the model in order to determine the validity of that model for that situation. Emphasis is on the construction or modification of models and not on the use of an existing model.

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[1] Drewes, D. W., "A Typology of World Views," Working paper #1, Project 6, Center for Occupational Education, North Carolina State University at Raleigh, North Carolina, August 1966.

Marc Belth (1945) has said that education presents models of the world to the student, teaches the student how to use the models and teaches the student how to evaluate the models. These ideas, when translated into the concepts above, indicate some support for the idea that the goals of education include cognitive openness as well as skill development. The Educational Policies Commission (1961) feels that one of the purposes of education is to enable a student to construct mental images in a new way and to understand different strategies of inquiry. Education for What is Real (1947) by Earl Kelley also suggested a goal of developing information processing ability in students. Harold Hodgkinson (1962) commented that the greatest service education can perform is to exist as a model of pluralism by not dogmatically denouncing certain ideas, but through confrontation of both publicly accepted and reflected ideas. Conflicting ideas must meet in the arena in a struggle for survival. The job of schools is to train students in the techniques of analyzing these ideas, so that they may be able to evaluate new ideas in any setting. Finally, S. S. Bloom in Taxonomy of Educational Objectives (1956) developed a hierarchical model of the goals of education in which the evaluation of ideas, concepts, models, etc., was the ultimate aim.

Since most of the authors reviewed had some concept which closely approximated the cognitive openness construct, it was decided that cognitive openness was one of the major goals of education. Education should give a student the ability to recognize a model as being nothing more than a model and instill in the student the capability to evaluate models according to the situation as well as modify any model for a given purpose. Consequently, cognitive openness was seen as one of the things which the educational system operated upon.

Education is seen as an operator which affects certain dimensions of student development. In mathematical symbology this can be represented as:

Education	(Cognitive Openness, Communication, Socialization, Critical Thinking, and Performance)
E	(C, S1, S2, S3, S4)

Specification of Output

Having specified the goals of education as operations upon a number of student dimensions, the next step requires a definition of the system output that will achieve the established goals. It was conceptualized that five indices for any school could be generated which would describe that school's ability to be effective in producing student changes along the five goal dimensions. Thus, one can refer to the school's effectuality, i.e., capability of producing an intended effect, for cognitive openness, critical thinking, communication, socialization, and performance development in students. A score for each of these five school effectualities will be considered the output of the proposed model.

Specification of Input

When one speaks of inputs, he must determine what goes into the system to be operated upon. Thus, the raw material, resources, or manpower that enable the school system to operate on students are often considered general inputs. One can also list a large number of specific school inputs, e.g., the number of teachers, the number of student seats, or the temperature of the drinking water. However, it is obvious that some inputs are more influential in educating students than others, i.e., they have a greater impact on the output. It is reasonable to assume that the compentence of the teacher is more powerful in developing student's critical thinking skills than the average size of the broom closets.

Of course, it is often difficult to separate the important from the unimportant inputs. The procedure followed in developing this model was to execute a survey of the educational research literature. This was done in order to determine the variables that educators deemed highly influential in the operation of any school. This activity required five months and the reviewing of hundreds of studies and articles. Any data that were felt to be of some possible use were collected. The specific inputs were postulated upon re-examination of all the collected materials. For a list of the model's inputs see Appendix A. Since there are well over a hundred of them, it would be unwise to discuss each of them independently.

It was also felt necessary to select all inputs as variables which are behavioral or observable. This restriction was imposed so that the inputs of any school system using the model would be readily accessible. Of course, this requirement also aids in the later quantification step.

Specification of Variable Relationships

The next phase of activity was the integration of all the collected information into a conceptual model. A twofold procedure was enlisted in this phase of the development of the model. First, each variable that was felt to be important was printed on a four inch by five inch index card. If the literature survey had indicated a relationship between the variable on the card and another variable, this was also printed on the card below the named variable. Secondly, a number of experts, e.g., educators, political scientists, sociologists, architects, psychologists, and some local school administrators were consulted for any insight or suggestions they might provide that might help in describing the variables and their relationships in a typical school.

The integration of the advice of experts and the variables supported by the research literature provided the basis for the conceptual model. A flow diagram of the final model is presented in Figure 6. A brief discussion of the actual content of the school model will be deferred to a later section.

Quantification of the Model

Variable Specification

Three processes were involved in the quantification stage of the construction of the model. It was first necessary to provide each variable with a numerical index which would be meaningful and comparable to other variable indices. The procedure that accomplished this task was a scheme based on national averages. Each variable was quantified so that a final index of "1" was assigned to a variable if the school value on that variable was equal to the national average. If any school under consideration scored below the national average, its index would be less than "1" on that variable. And, if any school scored higher than the national average on a variable, its index would be greater than "1". For example, the national average of money spent per school for the maintenance of the school plant is about $13.00 per student, as indicated by The Cost of Education Index (1965). If the amount spent on maintenance at a school under consideration is divided by this national average, then the index for that school will be somewhat less than "1" if the school spends less, "1" if the school spends the same amount, and greater than "1" if the school spends more than the national average.

Often, however, it was impossible to find national averages for certain of the variables that were present in the conceptual model. When there was no available data, some numerical index was arbitrarily chosen which was belived to be indicative of an adequate value for any school on that variable. Again, both the research literature and expert opinion were utilized in arriving at an a priori index. For instance, there was no statistic found on the national average of the amount of lecture versus the amount of discussion in the classroom. The literature did indicate that discussion is usually more beneficial for student understanding in most situations. Therefore, it was assumed that an adequate lecture versus discussion ratio was .8. Anything that deviates above or below this amount will reduce the value on this variable.

Relationship Specifications

Each relationship existing in the conceptual model must be quantified. The mathematical form of these relationships between variables must be stated. After examination of various mathematical functions, the relationships purported in the school model were generally considered to be linear. In lieu of strong evidence to the contrary, the formulae grouping together a set of variables are simple linear sums. Occasionally, however, two variables are obviously interactive. In this case the value of the two variables would be multiplied together. The 36 equations which relate all the variables together to provide five final indicators of the educational effectuality of the school are labelled in the schematic model and presented in Appendix B. Once again it is to be noted that none of these equations have been derived empirically but are, on the contrary, logically deduced.

Weighting Scheme

It has been demonstrated that all variables in the school system are not equally important. Some variables have more impact on the education of students than others, therefore, a weighting scheme is necessary to provide appropriate proportioning of influence in the model. In other words, the weighting scheme is a great deal like a value system. It determines just how much one values any variable in the model.

The equations in Appendix B are actually weighted linear combinations excepting the interactive combinations. Mathematically,

$$SV_i = a_k V_a + a_{k+1} V_b + a_{k+2} V_c + \ldots + a_{k+N} V_N$$

SV_1 is equal to one of the derived parameters and the a's are equal to the weights, while the V's are the values of the variables that are combined to produce the derived parameter. These weights are listed in Appendix C.

An important feature of this weighting scheme is that the weights of any given equation will at all times sum to one. Because all the variables are quantified so that they are approximately one when they equal the national average, the total value of any system variable will be approximately one when all the variables in that combination are one. And finally, the score of a school on any of the five output variables will be one if it scores on all the school variables are equal to the national average. For purposes of simplicity, these scores were all corrected to the base of 100. This base is often used and it is useful since deviations from that base can be understood as percentages above and below the base with little effort. Thus, if a school has an educational effectuality score of 100 for critical thinking skill development in students, then that school would be equal to the hypothetical average school in the nation. If that score increased to 110, then one can say that there was a 10 per cent increase.

Computerization of the Model

Once the model was quantified, it was a relatively simple task to translate it into a computer program. Each of the variables were given mnemonic code names and the equations relating them were written in Fortran V computer language. The code names are listed in Appendix A. An IBM 360/75 computer was used to debug the programmed model. The complete print-out of the program is presented in Appendix D. Once the values of the input variables have been determined and fed into a computer, it takes about 11.5 seconds to simulate any school in terms of its educational effectuality in reaching the goals of education which were previously stated.

DESCRIPTION OF THE SCHOOL MODEL

Introductory Remarks

Before a discussion of the school model is undertaken, certain prefatory comments need to be made. First, this is to be a rather brief description since only the important variables will be discussed. The exact quantification or mathematical definition of the variables will also be omitted. This is done so that the reader may achieve a better understanding of the total system without its being obscured by the technical aspects of two hundred variables. For instance, the variable, adequancy of school size, is operationally defined as

$$(400.0 - \left(\frac{\text{number of students}}{\text{number of grades}} \right) - 400.0 \ ) \ / \ 400.0$$

Essentially, the formula states that the adequacy of school size is maximum at 400 students per grade level. Any deviation from 400, above or below, will result in a decrease in the adequacy of school size score. The denominator, 400, corrects the index to unity as the scheme of quantification specified. The figure 400 is suggested by the Cooperative Research Project 918 (Hereford and Hecker, 1963) as the optimal number of students per grade level for student development in socialization and attitude formulation. Thus, one can see that any detailed examination of each variable would be lengthy and perhaps an uninformative approach.

Secondly, the discussion will follow the schematic flow chart found in Figure 6. The desired order of discussion is top to bottom and left to right in the flow chart of the model.

Finally, a few statements about the characteristics of the diagram need to be made. The darkest border indicates the school system's boundaries. All variables within this border are assumed to be inside the school and can be called system variables. All variables outside the border are variables from the community that penetrate the school boundary and influence the school. Usually, the community variables are of two types: (1) attitudes toward the school and education in general, and (2) financial resources. A light border has been placed around each observable or behavioral variable. These variables' values are quickly accessible through the administrative records of any school. These variables are termed fundamental parameters for purposes of identification. Derived parameters, designated by the medium dark borders, are variables that are not observable and are defined in terms of a combination of weighted fundamental parameters. Of course, the arrows indicate relationships that are present. Occasionally an arrow may have a small half loop. This merely indicates that the arrow does not join with the line beneath the loop. Lastly, each combination or equation is identified by a number.

Subsystems of the School Model

The first subsystem or combination of variables at the top of the flow model is the variable that indicates the attitude of the community toward the school system. It is felt that this subsystem, called Community Supportiveness, will have a great deal of influence on the effective functioning of the administration, the morale of the teachers, and the type of curriculum the school has to offer. In order to index the supportive attitude of the community, a group of five variables were selected that seemed to adequately reflect the supportiveness of the local residents. These variables are (1) the amount of indebtedness of the community for school bonds per student; (2) the amount of money paid by a community for its schools compared to its ability to pay; (3) the percentage of votes in favor of millage increase in the last millage election; (4) the proportion of the total revenue for the school which did not come from tax sources, e.g., student activities, non-resident tuition, and community rentals; and (5) the PTA membership per student. A weighted summation of these five indicators as specified by equation number 1 will provide a measure of community supportiveness.

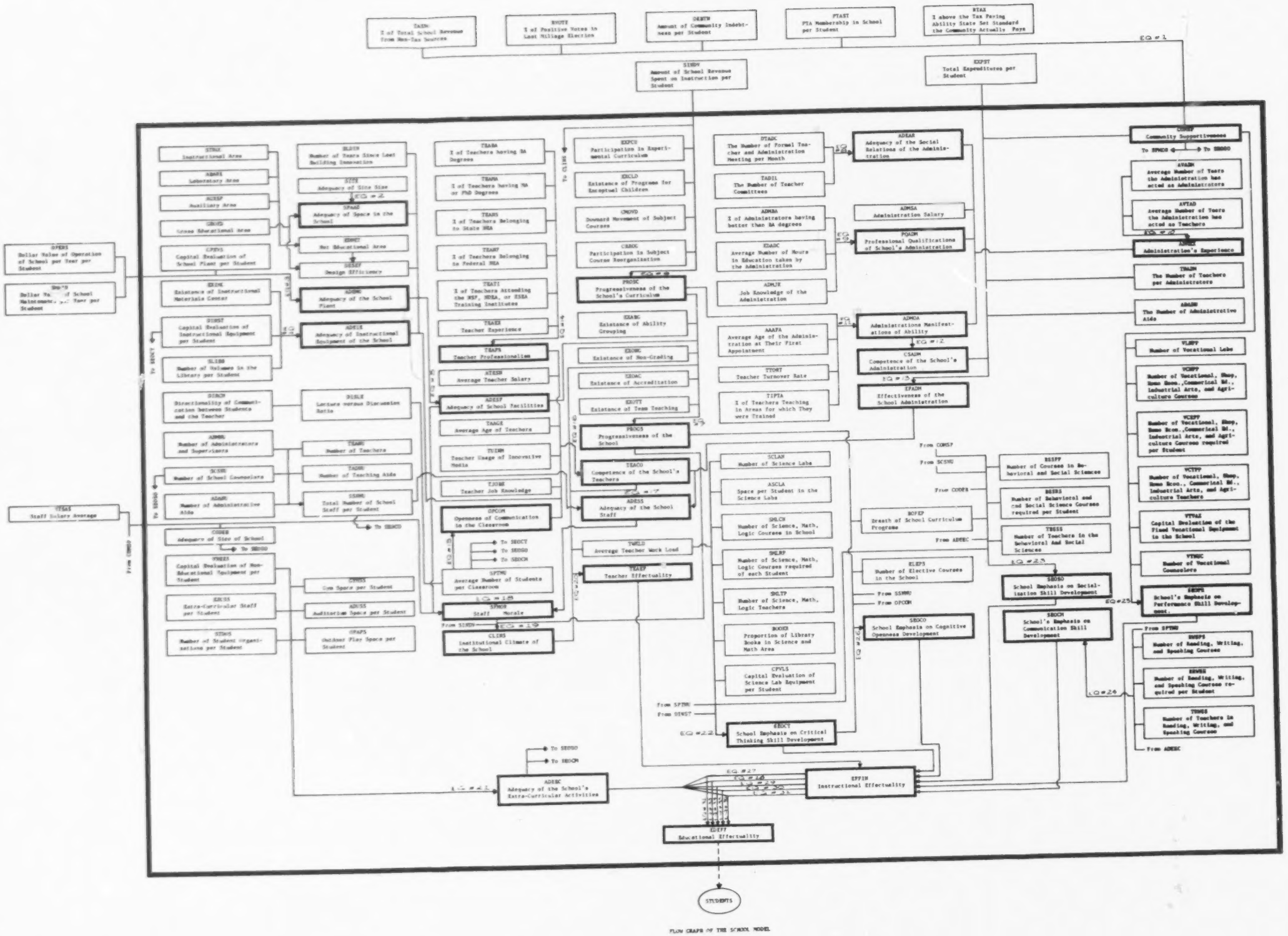
A second subsystem to the far left on the diagram is concerned with the facilities of the school. A net educational area is arrived at by adding the classroom, study hall, laboratory, cafeteria, library, and administrative office areas together. A gross educational area index is obtained by summating the areas of all the floors and the outdoor play area. A design efficiency index can then be calculated by dividing the net area by the gross area. The optimal design efficiency should be about 0.7 according to the American Association of School Administrators (1960).

The gross educational area is also combined with the adequacy of site size, whose averages are suggested by the National Council on Schoolhouse Construction (1964), to provide an adequacy of space in the school index. The adequacy of the school plant was obtained by comparing the capital evaluation of the school and the amounts of money spent on plant maintenance and operation with the national averages for these variables. This group of variables are related by equation number 3.

Another important aspect of the school facilities is the adequacy of the instructional equipment in the school. This subsystem was evaluated by determining the number of library books per student as compared to the national average of 6.0 (Coleman, 1966), whether or not an Instructional Materials Center exists, and, most important, the capital evaluation of the instructional equipment per student. Instructional equipment is defined as audio-visual equipment, demonstration equipment, and supportive equipment, e.g., typewriters and shop equipment.

A total facilities adequacy index may now be determined by combining (1) the adequacy of the instructional equipment, (2) the adequacy of space per student in the school, (3) the adequacy of the school plant, (4) the design efficiency of the school, and (5) the number of years since the last major building innovation. Equation 5 combines these

Figure 6. Flow graph of the school model


TAXR
% of Total School Revenue from Non-Tax Sources
BVOTE
% of Positive Votes in Last Millage Election
DEBTN
Amount of Community Indebtedness per Student
PTAST
PTA Membership in School per Student
RTAX
% above the Tax Paying Ability State Set Standard the Community Actually Pays
SINDV
Amount of School Revenue Spent on Instruction per Student
EXPST
Total Expenditures per Student
EQ = 1
STRAI
Instructional Area
ABARE
Laboratory Area
AUXSP
Auxiliary Area
GROSS
Gross Educational Area
CPIVL
Capital Evaluation of School Plant per Student
EDNE
Existence of Instructional Materials Center
EQUST
Capital Evaluation of Instructional Equipment per Student
SLIBR
Number of Volumes in the Library per Student
DIRCM
Directionality of Communication between Students and the Teacher
ADMIN
Number of Administrators and Supervisors
SCSVC
Number of School Counselors
AIDES
Number of Administrative Aides
CODES
Adequacy of Size of School
VMEES
Capital Evaluation of Non-Educational Equipment per Student
EXCSS
Extra-Curricular Staff per Student
STDES
Number of Student Organizations per Student
SLIBN
Number of Years Since Last Building Innovation
SIZE
Adequacy of Site Size
EQ = 2
SPACE
Adequacy of Space in the School
EDNET
Net Educational Area
DESEF
Design Efficiency
ADEQU
Adequacy of the School Plant
ADEQE
Adequacy of Instructional Equipment of the School
DIRLE
Lecture versus Discussion Ratio
TEARC
Number of Teachers
TAIDE
Number of Teaching Aids
SSTAF
Total Number of School Staff per Student
To SEDCO
To SEDCT
To SEDSO
To SEDCH
GYMSS
Gym Space per Student
AUDSS
Auditorium Space per Student
OPAPS
Outdoor Play Space per Student
TRABA
% of Teachers having BA Degrees
TRAMA
% of Teachers having MA or PhD Degrees
TEARS
% of Teachers Belonging to State NEA
TEART
% of Teachers Belonging to Federal NEA
TRATI
% of Teachers Attending the NSF, NDEA, or ESEA Training Institutes
TEAEX
Teacher Experience
TEAPR
Teacher Professionalism
ATESN
Average Teacher Salary
ADESF
Adequacy of School Facilities
TAGCE
Average Age of Teachers
TUINN
Teacher Usage of Innovative Media
TJOBK
Teacher Job Knowledge
OPCOM
Openness of Communication in the Classroom
SPTMU
Average Number of Students per Classroom
EQ = 18
STMOR
Staff Morale
From SINDV
EQ = 19
CLIRS
Institutional Climate of the School
To CLIRS
EXPCU
Participation in Experimental Curriculum
EXCLD
Existence of Programs for Exceptual Children
UNDVD
Downard Movement of Subject Courses
CHANC
Participation in Subject Course Reorganization
PROSC
Progressiveness of the School's Curriculum
EQ = 8
EXABC
Existence of Ability Grouping
EXNOG
Existence of Non-Grading
EXDAC
Existence of Accreditation
EXTTT
Existence of Team Teaching
PROGS
Progressiveness of the School
EQ = 16
TEACO
Competence of the School's Teachers
EQ = 17
ADESS
Adequacy of the School Staff
TWKLD
Average Teacher Work Load
TEAEF
Teacher Effectuality
EQ = 23
DTADC
The Number of Formal Teacher and Administration Meeting per Month
TADIL
The Number of Teacher Committees
ADMBA
% of Administrators having better than BA degrees
EDADC
Average Number of Hours in Education taken by the Administration
ADMJK
Job Knowledge of the Administration
AAFPA
Average Age of the Administration at Their First Appointment
TTORT
Teacher Turnover Rate
TIPTA
% of Teachers Teaching in Areas for which They were Trained
ADEAR
Adequacy of the Social Relations of the Administration
EQ = 9
ADMSA
Administration Salary
PQADM
Professional Qualifications of School's Administration
EQ = 10
ADMOA
Administrations Manifestations of Ability
EQ = 12
CSADM
Competence of the School's Administration
EQ = 13
EFADM
Effectiveness of the School Administration
From CORST
From SCSHU
From CODES
BOPEP
Breath of School Curriculum Program
From ADEEC
ELEPS
Number of Elective Courses in the School
From SSMHU
From OPCOM
SEOCO
School Emphasis on Cognitive Openness Development
SCLAN
Number of Science Labs
ASCLA
Space per Student in the Science Labs
SMLCH
Number of Science, Math, Logic Courses in School
SMLRP
Number of Science, Math, Logic Courses required of each Student
SMLTP
Number of Science, Math, Logic Teachers
BOOKD
Proportion of Library Books in Science and Math Area
CPVLS
Capital Evaluation of Science Lab Equipment per Student
From SPTMU
From DIRST
SEOCT
School Emphasis on Critical Thinking Skill Development
EQ = 22
EQ = 24
EQ = 25
EQ = 26
EQ = 27
EQ = 28
EQ = 29
EQ = 30
EQ = 31
EQ = 32
EQ = 33
EQ = 34
EQ = 35
EQ = 36
EQ =

variables into an adequacy of total school facilities measure.

In the middle top portion of the chart there is a derived parameter termed the progressiveness of the school's curriculum. It is composed of four discrete variables and the amount of money per student spent on instruction. The discrete variables, i.e., rated one or zero for existence versus non-existence in the school, are (1) existence of programs for exceptional children, (2) participation in an experimental curriculum, (3) any downward movement of subject courses, e.g., moving algebra 1 from the ninth grade to the eighth grade, and (4) any participation in subject matter reorganization, e.g., separating a broad field of study into component disciplines.

The progressiveness of the school curriculum is then combined with four other discrete variables and the adequacy of the school facilities to produce a measure of the progressiveness of the entire school. These four discrete variables are (1) the existence of ability grouping, (2) the existence of non-grading, (3) the existence of accreditation, and (4) the existence of team teaching. Equation number 7 provides for the combination of all these variables into an index of total school progressiveness.

The competence of the school's administration is defined by four derived parameters: manifestation of ability, professional qualifications, experience, and adequacy of social relations with teachers. Also, the variable, administrative salary, is added in this subsystem.

Administrative manifestations of ability consist of the progressiveness of the curriculum, the average age of the administration at their first administrative appointment, the teacher turnover rate, and the percentage of teachers teaching in the areas in which they have been properly trained.

Professional qualifications of the administration consist of job knowledge measured by scores on the National Teacher's Examination (Supervisory Section), the number of educational courses taken in training, and whether or not a masters or doctorate degree is held.

Administrative experience is gained from both the number of years as an administrator at that school and the number of years of teaching experience.

The adequacy of the administrative social relationships consists of the number of formal teacher-administrator meetings per month and the number of teacher committees per administrator.

The competence of the administration, defined above, is modified by the amount of money it has to spend, by the supportiveness of the community, the number of teachers per administrator, and the number of administrator aids (secretaries, bookkeepers) per administrator. All these variables, when combined, will provide an estimate of the total effectiveness of the school's administration.

Included in the teacher characteristics in a subsystem called teacher professionalism. This derived parameter attempts to describe teacher loyality or dedication to the teaching profession. It is made up of the amount of formal education the teacher has, the amount of teacher participation in professional organizations, the amount of experience as a teacher, and the amount of participation in extra teacher training. All of these fundamental parameters are corrected by the national averages, which can be found in the National Education Association Bulletin (1964) and/or the Cooperative Research Project 453 (Schmid, 1962).

The teacher profesionalism subsystem is added to teacher job knowledge, teacher usage of innovative media, teacher average age, teacher openness of communication with students, and the adequacy of instructional equipment to determine the competence of the school's teachers. The teacher-student openness of communication variable consists of a rating of the directionality (one way versus two way) communication of teachers and their students and a similar rating on the average ratio of class discussion to class lecture. Both ratings would be on rating scales expressing a proportion from zero to one. A score of .5 on the directionality of communication and a score of .8 on the discussion versus lecture ratio are assumed to be optimal scores. Those two variables are interactive and therefore are multiplied together. This product is then multiplied by the average class size index to give an openness of communication score.

The compentence of the teachers, the effectiveness of the administration and the adequacy of staff size which should be about one staff member per twenty students (NEA Education Policies Commission, 1959, p. 31) are combined by equation number 17 to produce an overall adequacy of the school staff index.

Then, staff morale and the progressiveness of the school and the amount of money spent on instruction per student combine to provide a derived parameter which estimates the overall institutional climate of the school.

Equation number 20 brings the institutional climate, the competence of the teacher, the average teacher work, and the adequacy of the facilities together to indicate the degree of teacher effectuality in the school. This index will describe the school's teacher's average capability to produce an intended effect (educate) on students.

Teacher effectuality operates interactively with five systems variables which describe the school's emphasis on developing students' output along the five dimensions. The critical thinking skill development emphasis index is influenced by the degree the school tries to stress quantitative and deductive reasoning with mathematics, logic, and science courses. Of course, size of class and money for instructional equipment are very important for this aspect. The school's emphasis on socialization skill development can be inspected by measuring the school's stress on social and behavioral science courses and the extra-curricular

activities adequacy as well as the breadth of the school program and availability of student counselors. Performance skill development emphasis can be evaluated by examining the vocational programs, vocational facilities, and the money put into teaching vocational skills to students. Communication skills are developed by the school's emphasis on courses which deal with reading, writing, and speaking. Also, the average class size and student participation in extra-curricular activities should be analyzed in determining the degree of stress a school places on communication skill development. Finally, the school's emphasis on cognitive openness consists of all the things which influence critical thinking, plus the degree of progressiveness of the school, the breadth of the school program index, the number of electives a school offers per student, the average number of students per classroom, and the openness of communication between teacher and student. Teacher effectuality is multiplied by each of these five school emphasis derived parameters to produce five indices of the instructional effectuality of the school. This is done by equations 27 through 31. (See Appendix B).

The adequacy of the school's extra-curricular activities, which has already been mentioned and which contains the dollar value of extra-curricular equipment, the number of extra-curricular staff, the gymnasium space, the auditorium area, the outside play area, and the number of student organizations is combined with the five indices of instructional effectuality to produce the five final output variables scores. These five final indices are called educational effectuality indices. Thus, there will be an educational effectuality score for cognitive openness, one for critical thinking, one for socialization, one for communication, and one for performance. These five indicators will describe any school's average potential effectiveness in educating its students in these five areas.

DEMONSTRATED USES AND POTENTIAL UTILITY

Evaluative Procedure

A measure of the correlational validity of the model is implausible because no external criteria exist against which one can correlate the results of the model. Therefore, as was discussed in the Introduction section, the most important criteria available for evaluating this model resides in its usefulness. If the model can demonstrate its utility in particular situations, there would be reasonable support for the contention that the construction of the model can be considered a worthwhile accomplishment. Three uses of the model are discussed in this section. These uses are (1) evaluation of existing school systems, (2) optimalization of outputs by varying fundamental parameters, and (3) production of information to aid in administrative policy making. These three uses are not mutually exclusive nor are they exhaustive of all possible uses; however, these examples will provide an indication of the possibilities the school model possesses for research and/or application to educational problems now present.

Evaluation of Existing School Systems

It will be remembered that the quantification scheme and the weighting system specify weighted combinations of ratios to produce a value to one hundred on any output variable if all the parameters equal the national averages. Therefore, a typical school in the United States should have the values of one hundred on all its derived parameters and output. This claim was verified by assigning the national average value to all fundamental parameters. Any fundamental parameter for which there was no national average was assigned the values that were assumed to be adequate. This data set (see Appendix E) was then simulated by computer. The results are found in Table 1.

The deviation of the scores from 100.0 is attributable to rounding errors. Thus, the hypothetical school with national averages will have output values of 100.0.

Of course, it is not probable that many schools will have values equivalent to the national average on most of their fundamental parameters. Schools with different values on fundamental parameters should have different values on their outputs. Moreover, schools with high values, i.e., values above the national average, logically should have educational effectuality scores of more than 100.0 Likewise, schools with values below the national average should have output values of less than 100.0.

A set of data was artifically produced for both a poor (scores that are 50 per cent of the typical school data) school and a good (scores that are 50 per cent above the typical school data) school.

Table 1. Simulation run of typical school data

Adequacy of school facilities	99.92555
Progressiveness of the school	99.95508
Effectiveness of the school administration	99.70583
Teacher competence in the school	99.77847
Adequacy of the school staff	100.12302
Staff morale in the school	100.07896
Institutional climate of the school	100.01764
Teacher effectuality in the school	99.90285
Adequacy of the school extra-curricular activities	99.86977
School's emphasis on cognitive openness development	99.87941
School's emphasis on critical thinking skill development	99.60808
School's emphasis on communication skill development	99.96144
School's emphasis on performance skill development	99.99059
Educational effectuality for cognitive openness	99.79985
Educational effectuality for critical thinking	99.58299
Educational effectuality for socialization	99.88057
Educational effectuality for communication	99.86540
Educational effectuality for performance	99.88870

These data sets can also be found in Appendix E. The results of the computer simulation of the poor school data are reproduced in Table 2 and the results of the good school are located in Table 3. Obvi-

Table 2. Simulation run of poor school data

Adequacy of school facilities	35.32062
Progressiveness of the school	12.39745
Effectiveness of the school administration	56.89384
Teacher competence in the school	48.39203
Adequacy of the school staff	48.74623
Staff morale in the school	50.97412
Institutional climate of the school	30.91786
Teacher effectuality in the school	52.47060
Adequacy of the school extra-curricular activities	39.77776
School's emphasis on cognitive openness development	21.14151
School's emphasis on critical thinking skill development	46.92903
School's emphasis on socialization skill development	34.30829
School's emphasis on communication skill development	43.95552
School's emphasis on performance skill development	31.50830
Educational effectuality for cognitive openness	16.83000
Educational effectuality for critical thinking	27.65469
Educational effectuality for socialization	22.35695
Educational effectuality for communication	26.40651
Educational effectuality for performance	21.18161

ously, the school model can separate schools which have differing fundamental parameter values.

Table 3. Simulation run of good school data

Adequacy of school facilities	131.98442
Progressiveness of the school	110.77174
Effectiveness of the school administration	112.40186
Teacher competence in the school	133.88928
Adequacy of the school staff	128.97977
Staff morale in the school	123.27538
Institutional climate of the school	120.04117
Teacher effectuality in the school	133.67653
Adequacy of the school extra-curricular activities	124.68729
School's emphasis on cognitive openness development	126.55934
School's emphasis on critical thinking skill development	142.60034
School's emphasis on socialization skill development	148.12373
School's emphasis on communication skill development	148.81238
School's emphasis on performance skill development	147.30396
Educational effectuality for cognitive openness	160.28146
Educational effectuality for socialization	183.34264
Educational effectuality for communication	184.07916
Educational effectuality for performance	182.46602

Administrators of a school may be interested in what areas their schools may be weak or strong. The evaluation usage of the model can provide this information quickly once the relevant data is collected. In fact, district or even national educational administrators can evaluate all or any of the school's under their supervision.

It is also possible that accreditation or school evaluating organizations would be interested in this type of approach in evaluating educational systems. At least, this type of approach provides explicit guidelines for the evaluation process which has so often been based on temporary subjective reactions.

Effect of Parameter Variation on Output

A second usage of the model is a systems design usage. One can vary the value of any parameter or set of parameters and observe the variation's effect on the output values. One may wish to know the relationship between class size and the educational effectuality for critical thinking skill development. One may be interested in what effect the attitude of the community toward education has on the performance skill development in students. Each of these questions can be answered by manipulating the values of concerned parameters, holding all other parameter values constant and the, observing the output.

Five examples of this usage of the school model will be presented.

One may inquire, for example, what would happen to the educational effectuality in achieving the stated goals of education if the average class size were increased from five students to 150 students. A graph plotted by the computer explains visually what occurs. Figure 7 shows the five output's effectualities plotted against increases in class size. It is also assumed for this graph that the lecture versus discussion ratio must decrease as class size increases and the lecture/discussion varies from 0.8 (optimal) to almost zero. Educational effectuality varies from 2.02 for a class size of 5.0 to 0.81 for a class size of 150. It is also reasonable to think that performance would be less effected by class size variation than communication and cognitive openness.

A second example of this type of utility purported by this model is increasing the fundamental parameters which influence average teacher competence in the school. Figure 8 shows the influence of teacher competence on educational effectuality. The teacher competence is increased from 1.00 to 1.25 in terms of the national averages and thereby represents a 25 per cent increase in the school's teachers' competence. This increase caused the cognitive openness skill development scores to increase about 17 per cent, while the four other outputs were increased about 8 per cent. The slope of all lines seems to be linear, and thus it can be suggested that higher increases in teacher competence will produce more and more educational effectuality.

People have often wondered if and how extra-curricular student activities affect the educational outputs. The model implied (see Figure 9) that as the adequacy of extra-curricular activities increased from 0.00 to about 2.00 or about 200 per cent, the outputs also increased. It is also interesting to note that the communication and socialization skill development scores were affected more than the other outputs. When the adequacy of extra-curricular activities was low, then communication and socialization lost the greatest amount; when it was high, communication and socialization gained the greatest amount. This result is also logical in that it would seem reasonable to predict that extra-curricular activities probably affect students communication and socialization skills more than anything else.

It is interesting to speculate about what would happen if a community became more supportive of education. Therefore, the model's implication for increases in community supportiveness were felt important enough to be examined. Only one of the five variables making up community supportiveness was varied: the ratio of amount of money actually paid in taxes for schools divided by the amount of money which the community has been assessed as being able to pay. This fundamental parameter is increased from 1.00 to 2.00, and community supportiveness changed from 1.00 to 1.40. These changes produced the graph seen in Figure 10. Increases in the tax ratio had very little or no influence on communication, cognitive openness, and critical thinking skill development. Socialization skills were increased about 2 per cent and

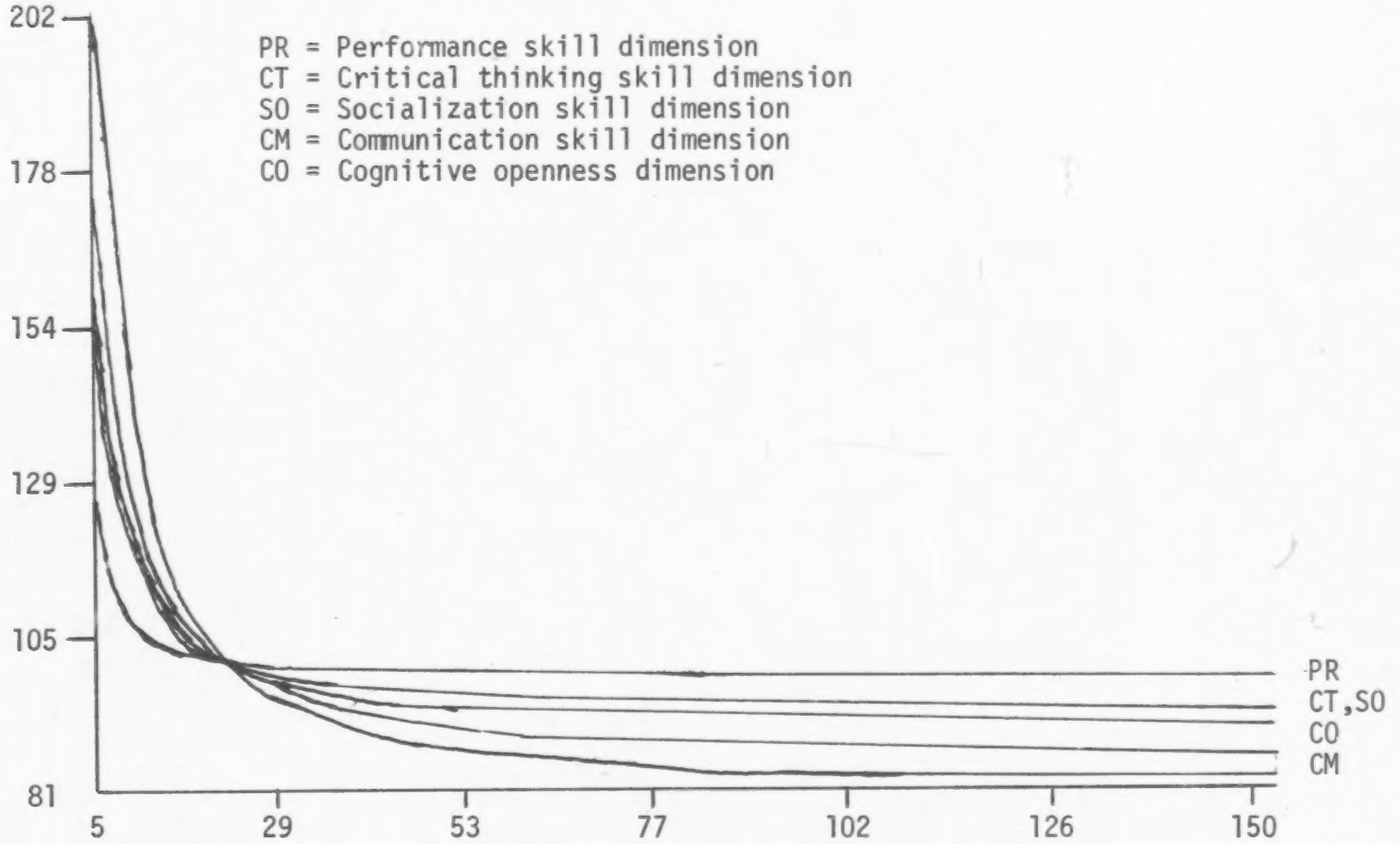


Figure 7. Plot of class size increments and lecture discussion ratio decrements against the final model output

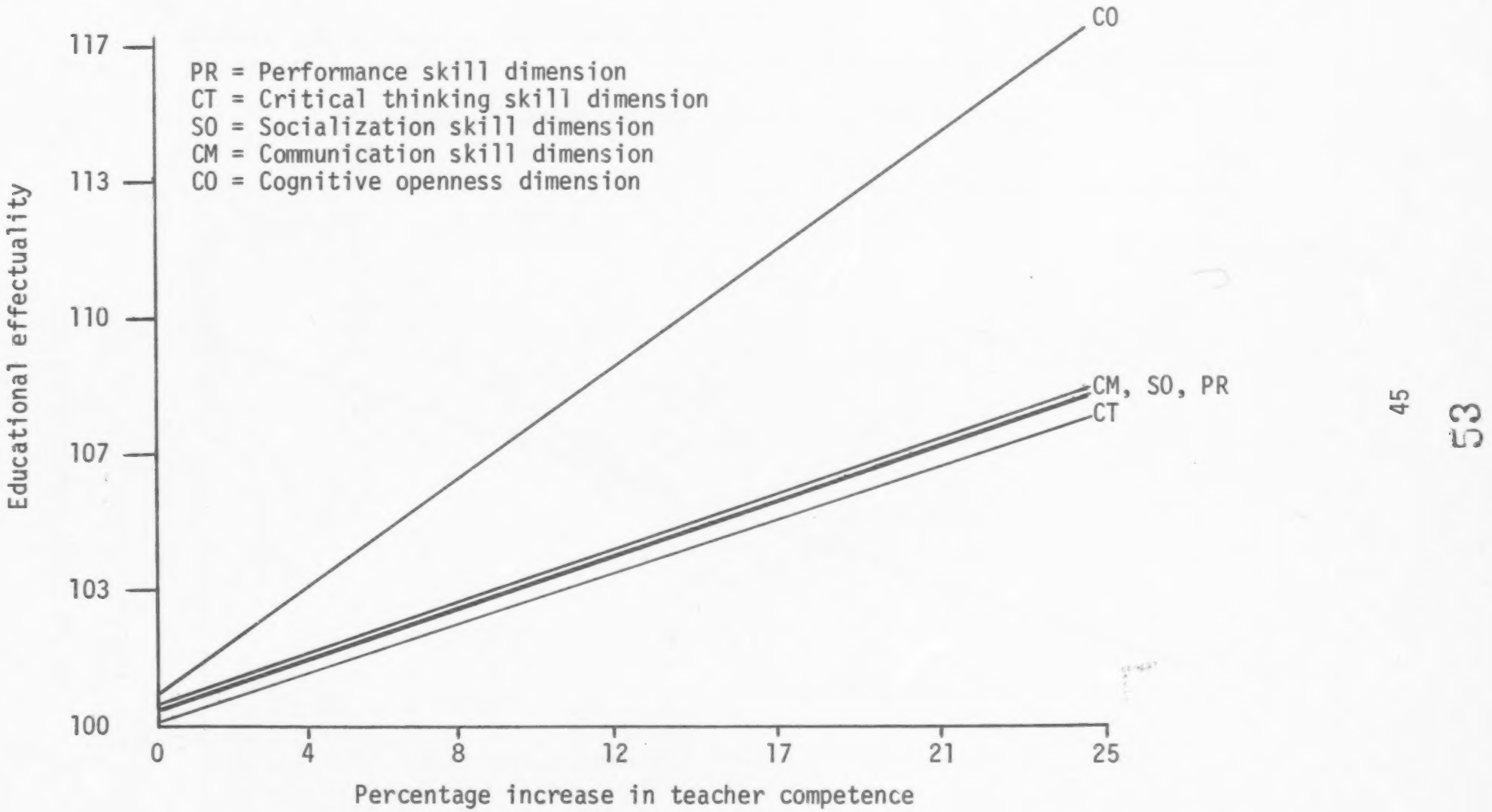


Figure 8. Teacher competence increments plotted against educational effectuality outputs

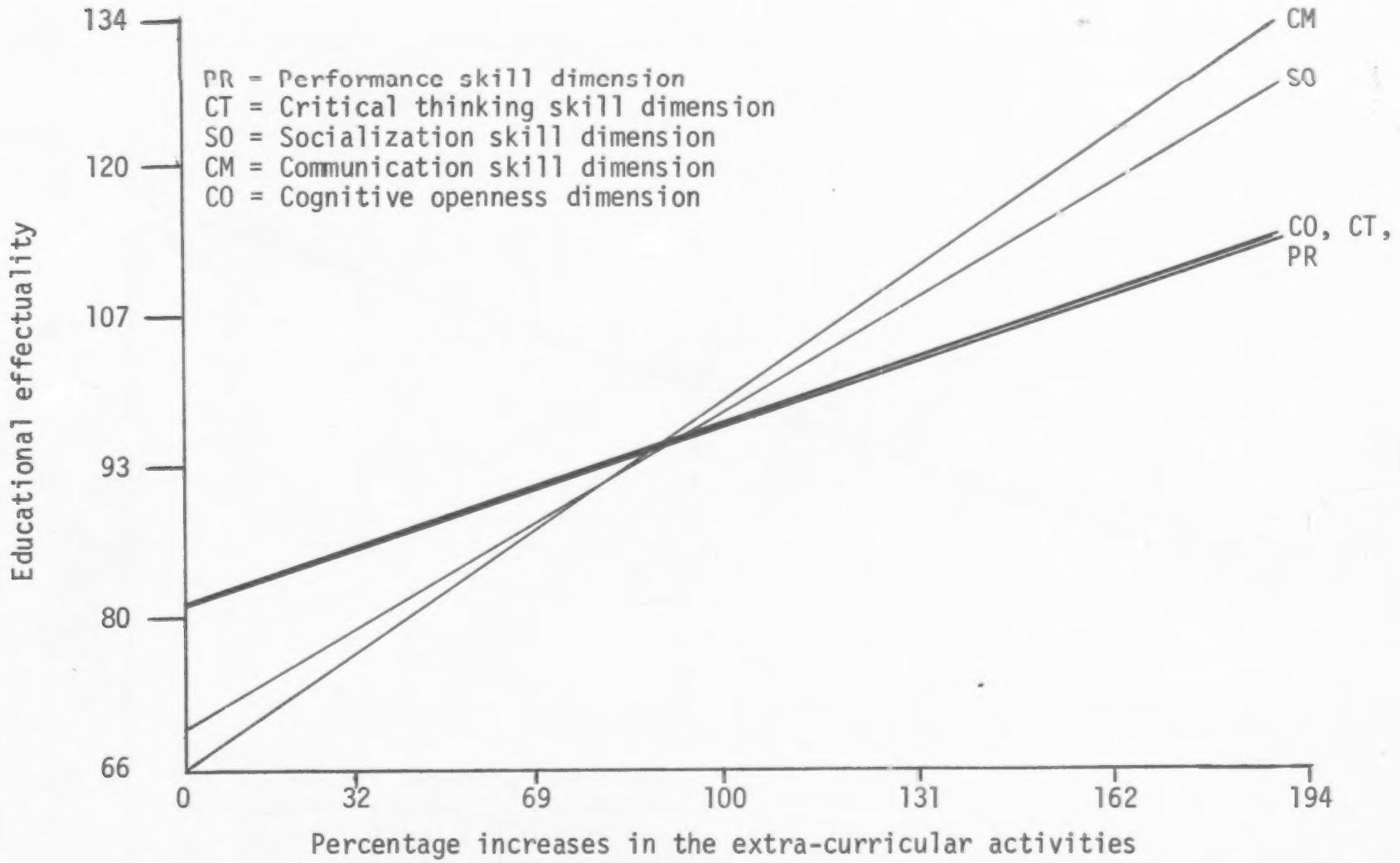


Figure 9. Increments in the adequacy of the school's extra curricular activities plotted against the school's final outputs

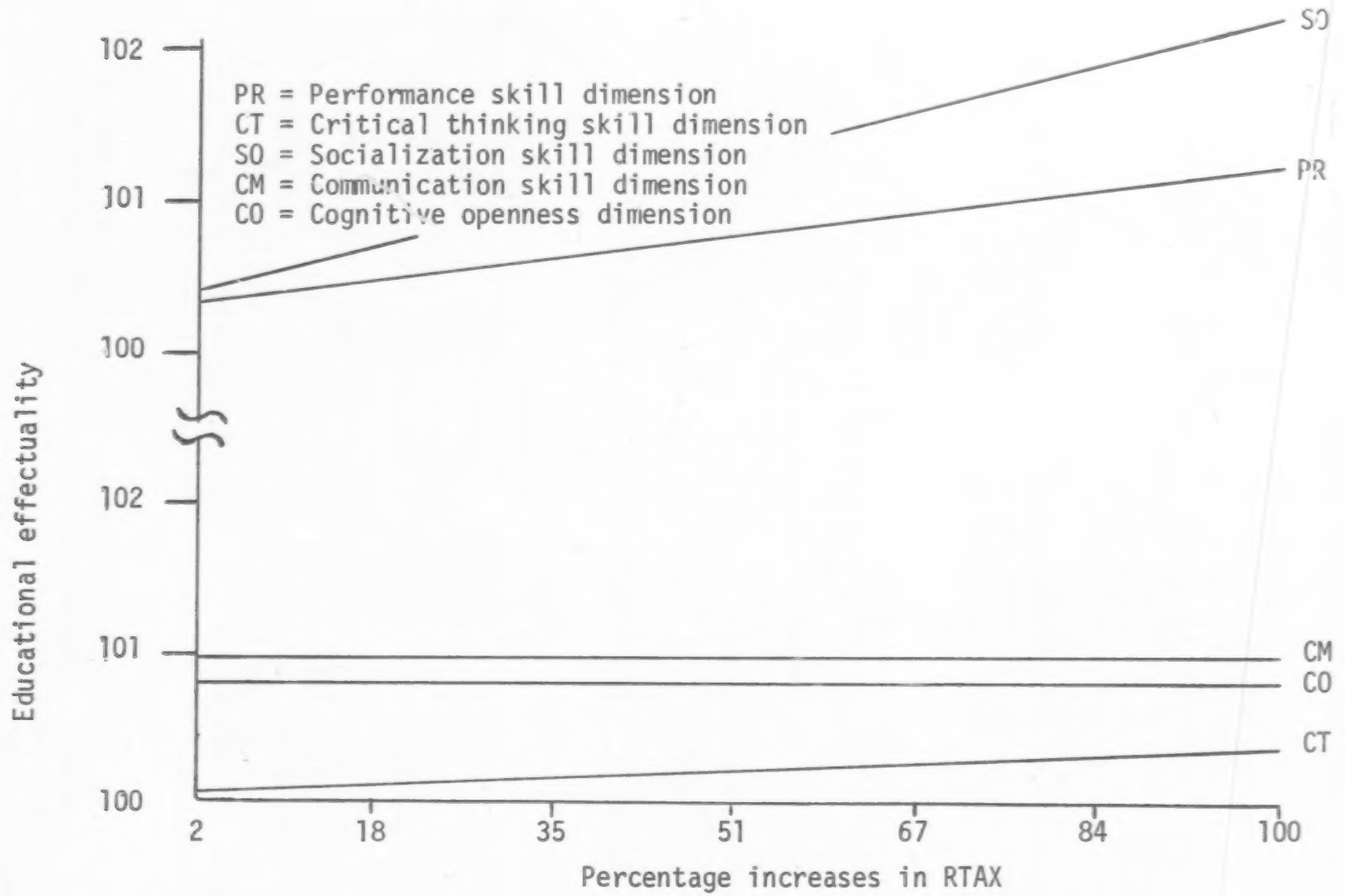


Figure 10. Plot of ratio of community's ability to support its schools and the monetary amount actually spent on education against educational effectuality

performance skills had about 1 per cent increase. These changes represent relatively small increments in the outputs when one considers that the community pays twice its usual amount for schools. However, in a two hundred variable system, one can hardly expect very much influence from the changes in only one fundamental parameter. Changes in outputs are usually significant only if a number of variable values are changed.

A final example for parameter variations is seen in Figure 11. This graph portrays incremental changes in all the capital evaluation variables in the model. In other words, the plant, the fixed laboratory equipment, shop equipment, and instructional equipment are increased. Their values change from 1.00 to 1.90 equally--an increase of 90 per cent. All the outputs change substantially and seem to be positively linear. Performance and critical thinking skill development outputs are affected more than the remaining three outputs' variables. This may be due to change in science laboratory equipment for critical thinking and shop equipment increases for performance. And again, it is logical that these two variables are influenced more by equipment changes than socialization, communication, or cognitive openness.

Information for Administrative Policy Making

Each time an administrator adopts a policy or makes major decisions, he must utilize a strategy which he thinks will be most beneficial. Often the school administrator must select a strategy from an alternative set of strategies while he is seriously hampered by a lack of information. The school model can simulate any number of strategies and show the results obtained by applying a strategy. Thus, one could simulate the alternative strategies an administrator has at his disposal, and then determine which option would provide him with the most benefit in terms of the goals he has in mind.

The computer model can be manipulated in several ways to show how alternative strategies compare. One may examine the final outputs which are derived from the strategies. This essentially means the comparison of the results of alternatives at a single point. An example of this type of approach will be discussed in the next paragraph. A more useful approach involves the comparison of alternative strategy results at a number of points. This would provide information about strategies that are less beneficial at some points than at other points. For instance, it may be wise for an administrator to follow a particular strategy up to a point and then change to a more effective strategy. Examples of this type of approach will also be discussed later.

If a given school is only about 50 per cent adequate in its facilities, the administration is probably concerned about how to raise the school's educational effectuality. There are a number of different ways in which this can be done and the administrator must select a strategy from a number of alternative ones. For example, let one of the strategies be called Policy A which consists of increasing the entire school personnel's ability

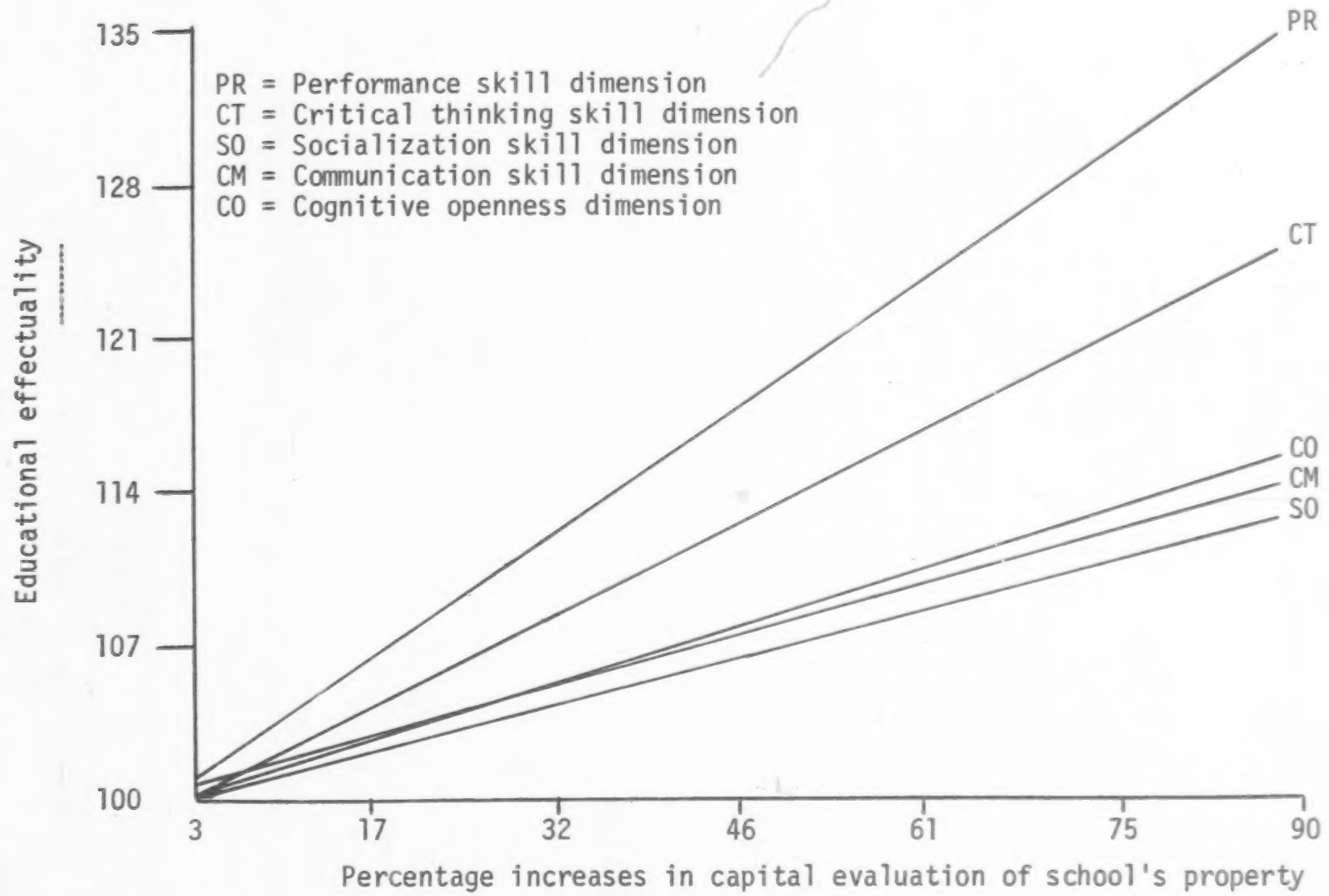


Figure 11. Increments in the capital evaluation of school property plotted against the educational effectuality of the school's outputs

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75 per cent and increasing the school's equipment 25 per cent. Let a sec- one strategy, Policy B, consist of a 25 per cent increase in the school personnel's ability and a 75 per cent increase in the equipment of the school. Policy C is made up of a 50 per cent increase in the school personnel's ability and a 50 per cent increase in the equipment. Which of the policy decisions will provide the most educational effectuality is the question that the administration wants answered. The computer model loaded with the desired parameter values provides the information in Table 4.

Table 4. Administrative policy making information presents output scores for different policies

	Policy A - increase personnel 75% and equipment 25%	Policy B - increase equipment 75% and personnel 25%	Policy C - increase equipment 50% and personnel 50%
Performance	94.8801	105.8160	102.219
Communication	99.4492	98.0526	100.5320
Cognitive Openness	98.2347	100.1060	101.1840
Critical Thinking	96.6402	103.2460	101.8970
Socialization	99.8752	98.4713	100.9630

One observes that all the policy decisions will produce approximately the typical outputs of 100.0. However, if the administration wanted to improve performance educational effectuality, Policy B is 11 per cent better than Policy A. Other outputs of the different policies can also be compared and the best alternative strategy can be selected based on the information provided by the simulated model. Under Policy B performance and critical thinking scores are highest, while communication is lowest. Therefore, there is a great amount of interaction in the policies and skill development scores. This exemplifies the interactive nature of educational systems.

Instead of looking at a particular point, e.g., increase of 75 per cent in personnel ability, it is usually more useful to examine a continuous function that can be deduced from the analysis of a large number of points. This is especially true if two functions are interactive. Thus, a locus of a set of points will provide a continuous index of educational effectuality. A good example of this approach will be described. Suppose an administrator wants to increase the cognitive openness in his school. Increasing the average competence of the school's teachers or increasing the number of electives per student,

the breadth of the school's program, the science laboratory space and equipment, and the number of books on science, mathematics, and logic are two or the possible strategies available for achieving this result. Figure 12 shows the results of these two strategies if increments of 5 per cent beginning at 0.5 for both are simulated 30 times. The graph suggests that if one wants to increase the educational effectuality to about 1.10, then the best strategy to follow is to increase the competence of the teachers; however, if one is interested in reaching higher levels of cognitive openness, it is best to change strategies at that point. Therefore, looking at a number of points can provide much more information than looking at a single point representing one final output. Again, the interactive nature of these policies is apparent.

Another example of model simulation to provide information for decision making is offered in Figure 13. This figure shows the incremental changes in the five outputs as functions of increases in teacher competence when the school's facilities are poor. Suppose the adequacy of a school's facilities is about 50 per cent of the typical value and an administrator wants to know if by increasing his teacher's ability he can reach the typical values for educational effectuality. That is, will teacher competence override bad facilities? Can very good teachers make up for poor facilities? The graph suggests that in order to obtain the typical value on the outputs, one must increase teacher competence at least 25 per cent above the nationally typical value. Thus, it may be possible to make up for very poor facilities with teacher competence, but it is extremely difficult. In fact, for performance skill development, the teacher competence must be increased a great deal more.

Suppose that the facilities are at 50 per cent of the adequacy level as in the example in Figure 13. Will increases in the school's educational equipment lift the educational effectuality outputs? The graph in Figure 14 answers this question. Here, the educational equipment is incrementally changed from 50 per cent to 350 per cent, in units of 10 per cent. As the dotted line indicates, increasing educational equipment will bring performance, critical thinking, and cognitive openness scores above the adequacy of 100. To increase performance scores to 100, it takes a 100 per cent increase in the educational equipment. To increase critical thinking scores to 100, it takes a 150 per cent increase in the educational equipment. A cognitive openness score of 100 requires about 200 per cent increase in the educational equipment of the school.

Up until now, nothing has been said about the cost of any of the variables which are changed during simulation. This has been avoided because a cost accounting model is not available for this school model. However, the model does have some money variables which can be manipulated. For instance, if a school obtained $50,000 increases in its total revenue, an administrator is certain to wonder how he can best allocate this new resource. Three possible uses of this money are (1) allocate to teacher salaries, (2) allocate to administrative salaries, or (3) allocate to institutional purposes. Which of these options will provide the most educational effectuality in students?

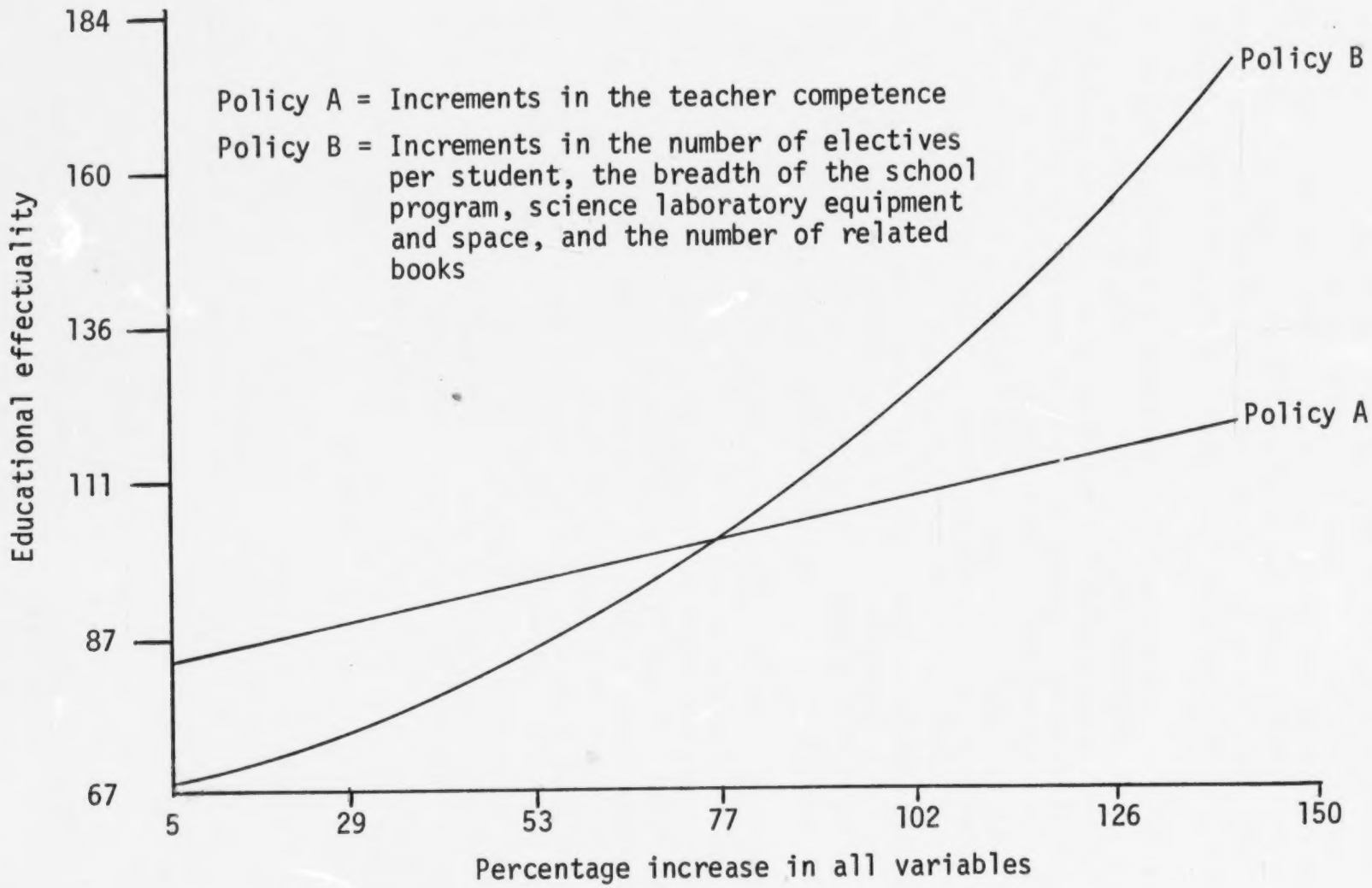

Figure 12. Information for decision making concerning cognitive openness

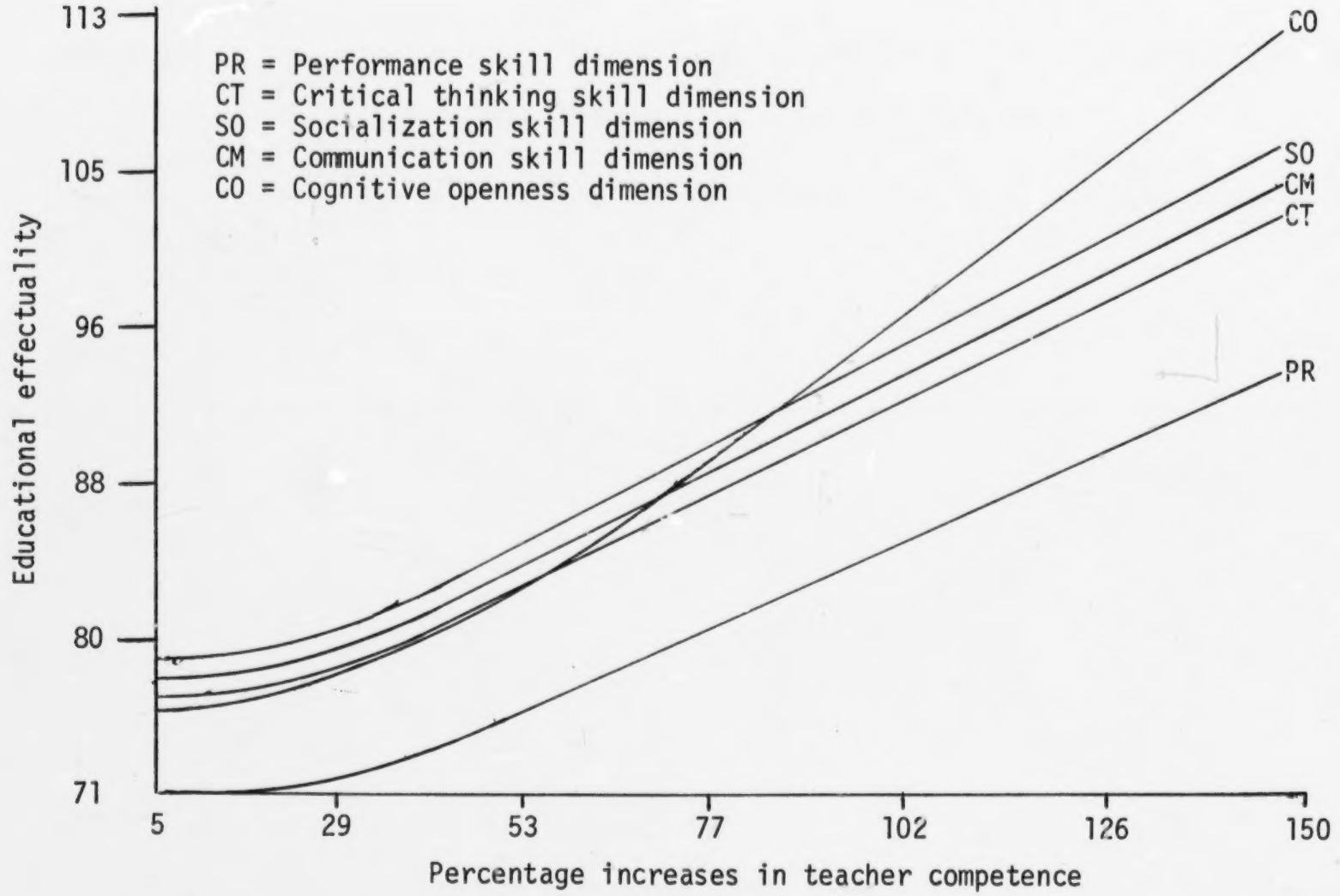

Figure 13. Increments in teacher competence from an adequacy score of 50 to 200 while the adequacy score of the school's facilities remains constant at 50 per cent of the desirable level

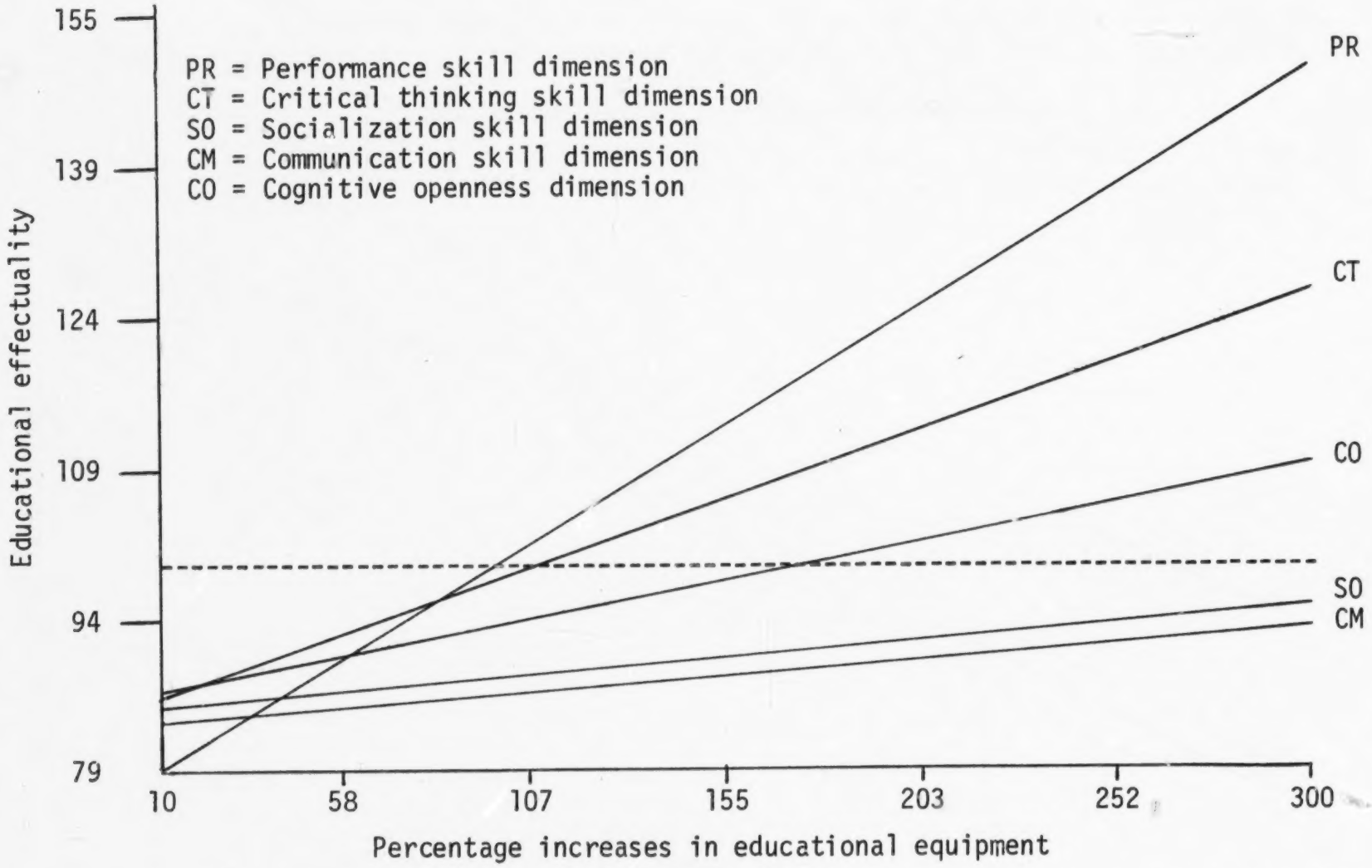

Figure 14. Plot of educational equipment increases when the school's facilities are 50 per cent adequate

Figure 15 shows what happens to the five outputs as total revenue is increased 150 per cent and all this money is directed into teacher salaries. One can see that this policy does not produce very much increase in educational effectuality. Although the lines are positively linear, they do not increase very much. In fact, they increase less than 1 per cent. Therefore, it is not too productive to put this extra money in teacher salaries.

Figure 15 also shows the results of the policy of putting the total revenue increments into administrative salaries alone. The slopes of the lines are likewise positive and linear, but again there is less than a 1 per cent increase in educational effectuality for any of the five outputs.

When the money allotment is put into instruction only, Figure 16 is the resulting diagram. The cognitive openness scores increased as much as 22 per cent, while the remaining four outputs went up almost 12 per cent. Therefore, it is easy to conclude that the administrator should put his extra money into instruction.

Of course, it is also possible to have the $50.00 increments proportioned to all three policies. One could put one half of the money in instruction and the other two quarters into teacher and administrator salaries. Indeed, there are an infinite number of possible proportions which could serve as different policies. An example of one such proportioning of the revenue increments can be found in Figure 17. Here the money is equally divided into the teacher salaries, administrative salaries, and instruction.

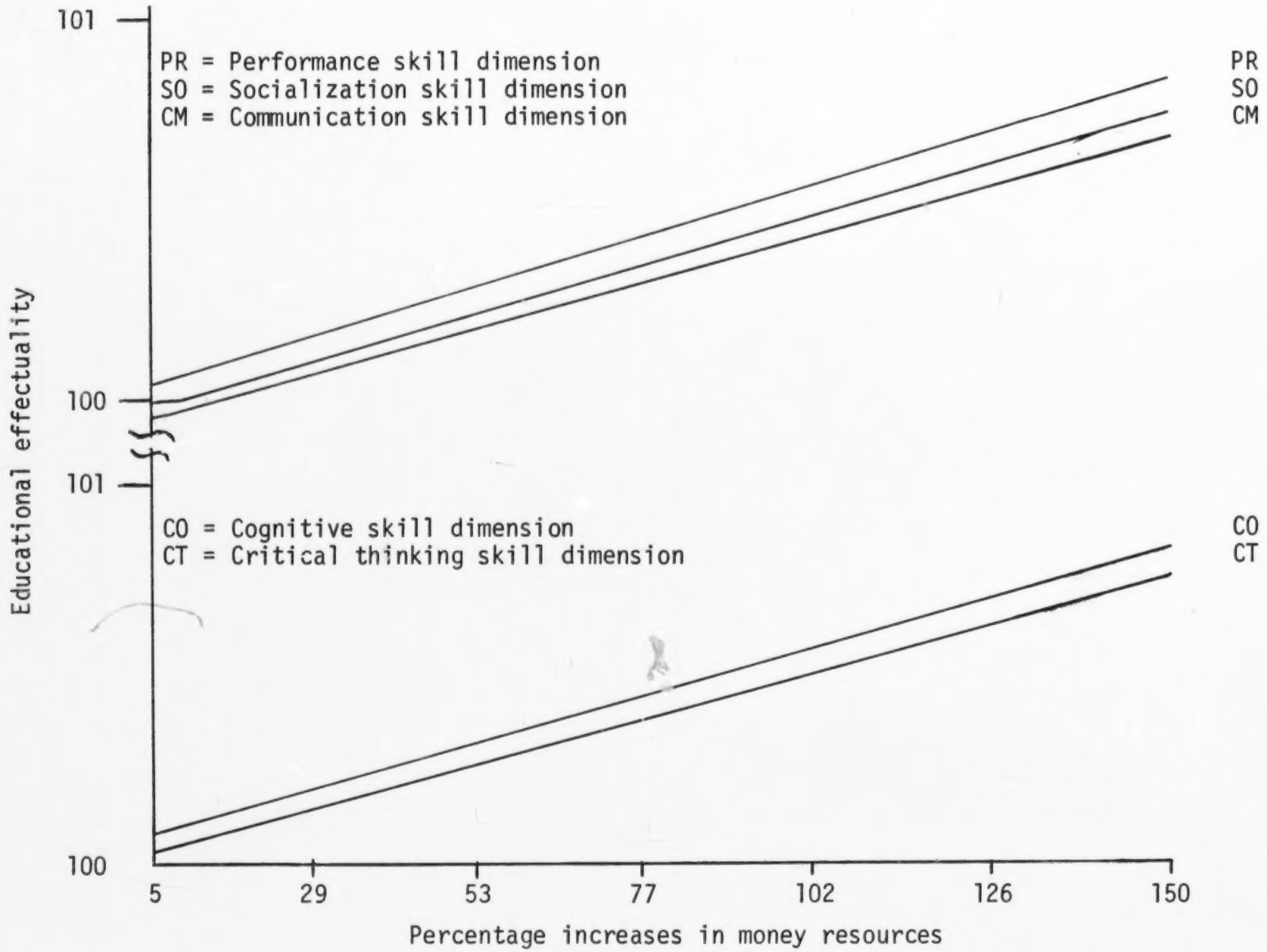

Figure 15. Allocation of money resources to either teacher salary or administrative salary

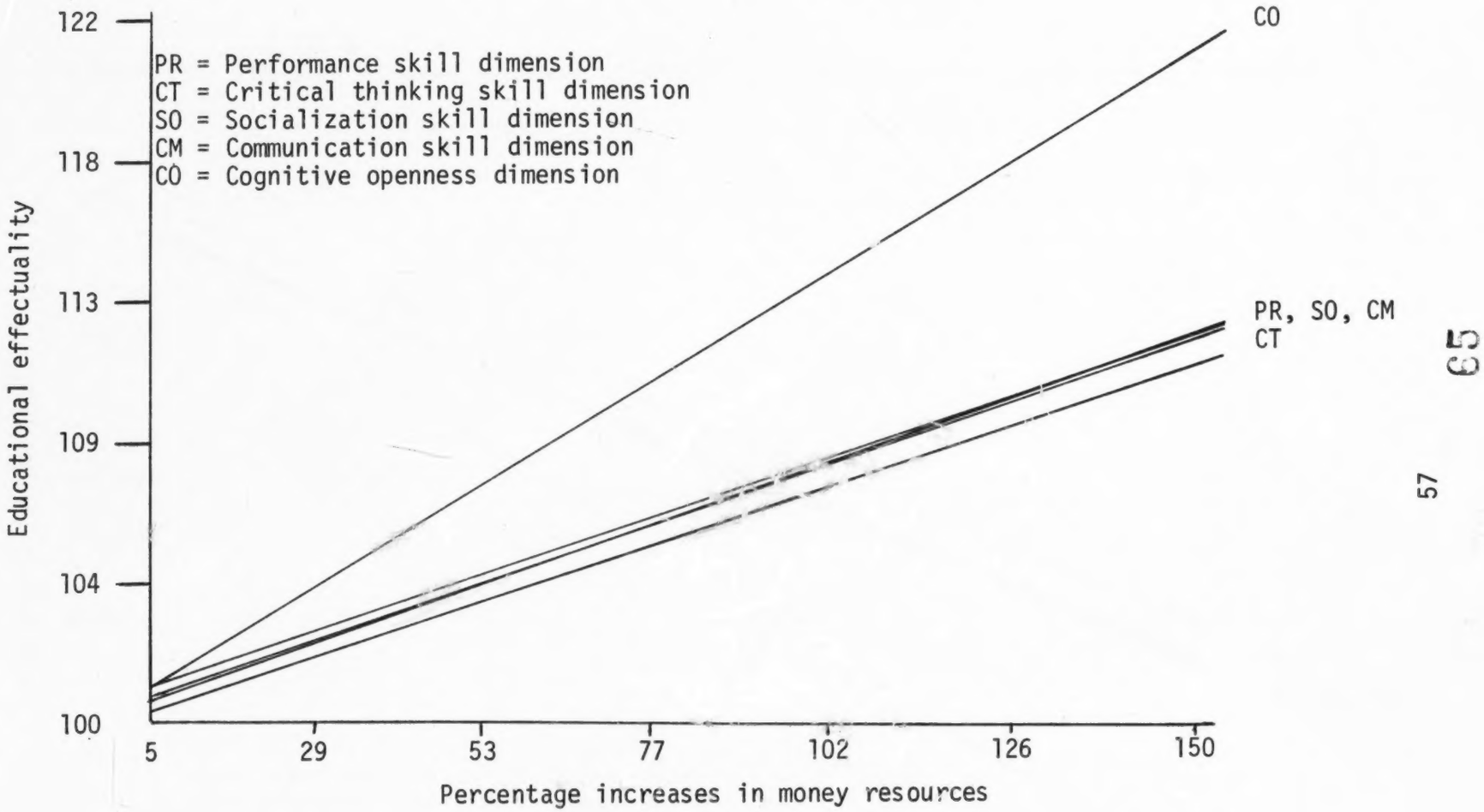

Figure 16. Allocation of money resources to instruction

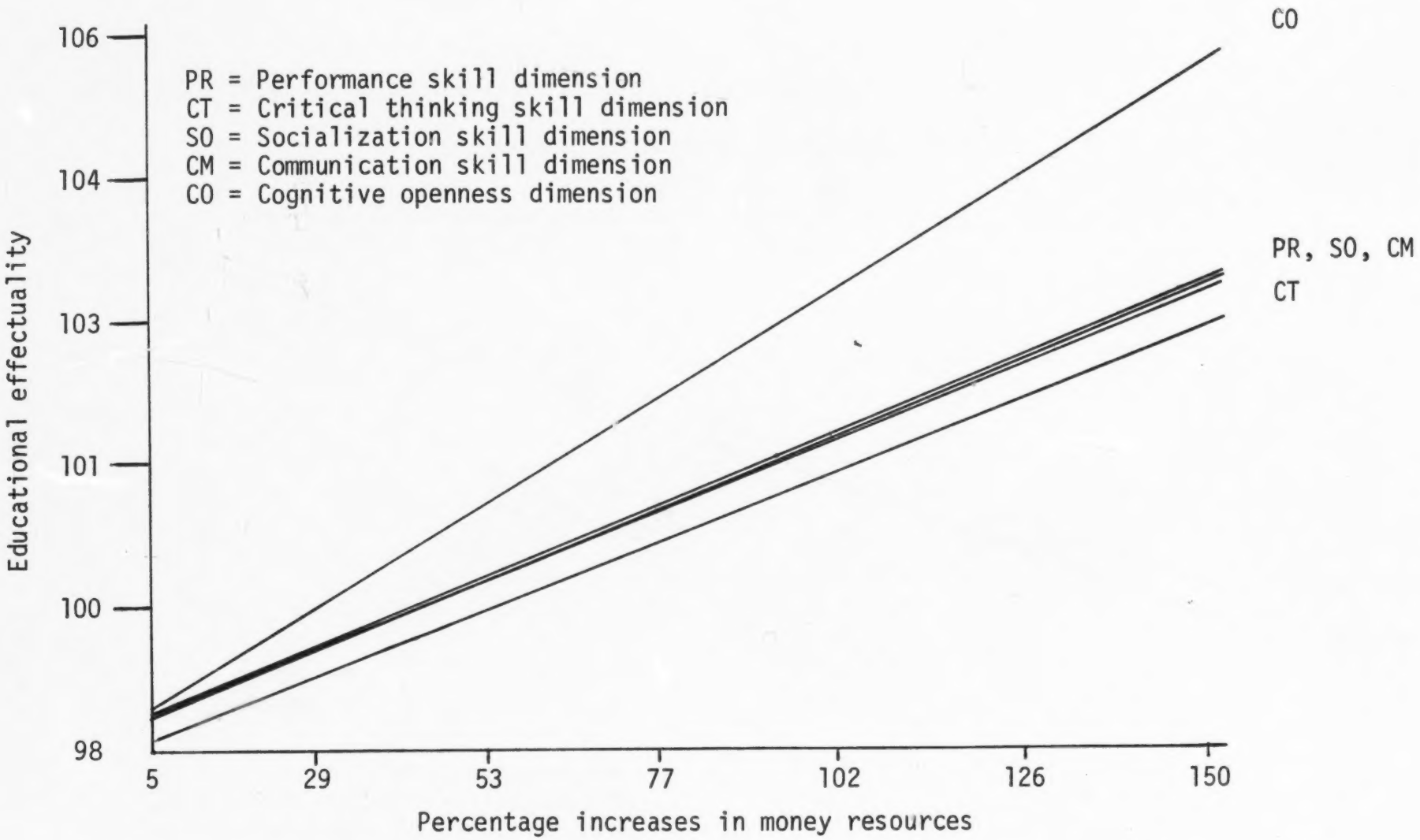

Figure 17. Equal allocation of money resources to teacher salary, administrative salary, and instruction

SUMMARY AND CONCLUSIONS

This report develops a theory of the operators on education. It is a theory of what goes into education, what happens in a school, and what is produced by an educational system. There are many theories of education, yet this theory is quite different from most--this theory is explicit. Any part of the theory may be inspected and tested.

This educational theory is thought of as a higher order theory, because it is in the form of a mathematical model. Since the model is constructed from the procedures developed by general systems theorists, a discussion of systems theory of the concept of models, and the idea that education can be considered as a system is included. Each step of the process of constructing the school model is described. Finally, some implications of the completed model are generated to demonstrate the usefulness of this type of approach to educational problems.

It should be mentioned here that it is felt that the generated implications of the model appear to have offered some face validity for the model as well as pointing out the tremendous potential models have in education. It is also believed that the school model can be used to suggest and test a large number of hypotheses and/or solutions to present educational problems. Therefore, it may have considerable utility as a research instrument.

It is very important to note that this model of the school is not being presented as the absolute model. No claim is made that this is a model of the final form of the school. However, the formulation of the functional form of the school is being attempted. That is, the structure of the operations of the school is the subject matter of this investigation. This allows the value system to be changed without damaging the model. Thus, if one values a variable more or less than is presented in the model, the variable weight may be changed to conform to one's wishes. Investigators may change the value system of this model entirely to be compatible with their own set of values for education. Therefore, the model is relative to the value system which it has.

The statistics on which the school model is based will change from time to time. National averages will vary and the model in its present form will be obsolete. Fortunately, it is simple to update the model as the statistics change. One can merely substitute the later averages for the outdated averages in the ratios of the model.

Disregarding the practical value of the model itself, one conclusion can be made which is of importance. It has been demonstrated that decision making, mathematical, simulation type models of the educational system can be constructed. This is clearly a feasible undertaking. Although the practicality of such models may still be questioned, the issue is no longer one of feasibility.

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Appendix A

Variables: Mnemonic Code Names and Definitions

APPENDICES

Variable names and definitions are arranged according to the sequence of the computer model.

1. STDNU - the number of students currently enrolled in the school

2. TAXUS - the amount of revenue from non-tax sources including (1) tuition from non-resident students, (2) cafeteria sales, (3) student activities, (4) community rentals and services, and (5) miscellaneous

3. TAXNT - the total amount of revenue for the school during the past year

4. TAXNO - TAXNS/TAXNT

5. PVOTE - the number of positive votes in the last millage election

6. TVOTE - the total number of votes in the last millage election

7. RVOTE - PVOTE/TVOTE

8. STTAX - the standard set by the state or assessment agency for the amount of tax the community is able to pay for its schools

9. PDTAX - the actual amount of money the community paid for its schools in the past year

10. RTAX - PDTAX/STTAX

11. DEBT - the amount of community indebtedness for school boards

12. STDNA - the number of students in the area of the community

13. DEBTN - (DBT/STDNA)/400--400 is the national average for bond indebtedness

14. PTAMB - P.T.A. membership in the school

15. PTAST - PTAMB/STDNU

16. COMSP - community supportiveness (derived parameter)

17. CLASS - the square feet of space in all teaching classrooms

18. STUDY - the square feet of space in all study halls or individual study carrells

19. STRUC - CLASS + STUDY

20. ARTSP - square feet of space for art activities

21. HOME - square feet of space for home economics activities

22. SHOP - square feet of space for shop activities

23. COMED - square feet of space for commercial education activities

24. ABSPA - square feet of space for science and language laboratories

25. AUDAR - square feet of space for auditorium area

26. CAFET - square feet of space for cafeteria area

27. ABAND - square feet of space for band room area

28. ALIBY - square feet of space for library area

29. ARGYM - square feet of space for gymnasium area

30. ADSPC - square feet of space for administrative offices area

31. ABARE - ARTSP + HOME + SHOP + COMED + ABSPA

32. AUXSP - AUDAR + CAFET + ABAND + ALIBY + AGYM + ADSPC

33. EDNET - STRUC + ABARE + AUXSP

34. FLOOR - square feet of space for all developed floors including basement

35. EXTRA - square feet of space for all porches, porticoes, passages, and stairs

36. PLAY - square feet of space for all open and covered play or athletic areas

37. GROED - FLOOR + EXTRA + PLAY

38. DESEF - EDNET/GROED - design efficiency

39. SITE - number of acres of entire school grounds

40. SPAAD - adequacy of space in the school per student (derived parameter)

41. DMAIN - amount of money spent on school maintenance, including school repairs and maintenance men's salaries

42. SMAIN - (DMAIN/STDNU)/13--13 is the national average per pupil for maintenance

43. OPERA - the amount of money spent on school operation which includes custodial salaries, heat, utilities, etc.

44. OPERS - (OPERA/STDNU)/40--40 is national average per pupil for operation

45. CPEVL - capital evaluation dollar value of the existing physical plant

46. CPEVS - (CPEVL/STDNU)/1000--1000 is national average per pupil for capital evaluation of school plant

47. ADEMO - adequacy of school plant facilities (derived parameter)

48. EXIMC - existence of instructional materials center (Yes = 1; NO = 0)

49. DINST - capital evaluation dollar value of all instructional equipment included in audio visual equipment, demonstration equipment, e.g., models of the human skeleton, and supportive equipment, e.g., typewriters, shop tools, etc.

50. DINSN - (DINST/STDNU)/95--95 is assumed to be an adequate index of capital evaluation of instructional equipment per student

51. BOOKL - number of books in the school library

52. SLIBB - (BOOKL/STDNU)/6--6 is the national average of books per student

53. ADEIE - adequacy of instruction equipment of the school (derived parameter)

54. BLDIN - number of years since the last major building innovation (if within the last year, tally 0; the last two years, tally 1, etc.)

55. ADESF - adequacy of the school facilities (derived parameter)

56. EXPCU - the school's participation in any experimental curriculum (YES = 1; NO = 0)

57. EXCLD - the school's having programs for exceptional children (YES = 1; NO = 0)

58. CMOVD - the school's participation in any downward movement of subject courses, e.g., moving Algebra 1 from ninth grade to eighth grade (YES = 1; NO = 0)

59. CRROG - the school's participation in any subject reorganization, e.g., dividing general area of study into component disciplines (YES = 1; NO = 0)

60. DVINS - the amount of money spent directly on instruction. This included teacher salaries, supplies, teaching aids, and other professionals, e.g., psychologists

61. SINDV - (DVINS/STDNU)/300--300 is national average of instruction money per student

62. PROSC - progressiveness of the school's curriculum (derived parameter)

63. EXABG - the existence of an ability grouping program in the school (YES = 1; NO = 0)

64. EXONG - existence of a non-grading program in the school (YES = 1; NO = 0)

65. EXOAC - existence of accreditation in the school (YES = 1; NO = 0)

66. EXOTT - existence of team teaching in the school (YES = 1; NO = 0)

67. PROGS - progressiveness of the school (derived parameter)

68. DTADC - number of formal meetings of teachers and administrators per month

69. DTADN - DTADC/2--2 is assumed to be an adequate index

70. TADIL - number of teacher committees

71. ADMNU - total number of administrators which include superintendent, associate or deputy superintendent, director, co-ordinator, consultant, supervisor, principal, assistant principal, and the heads of all departments

72. DADIR - (TADIL/ADMNU)/3--3 is assumed to be an adequate index

73. ADEAR - adequacy of teacher and administrative directionality of communication and level of interaction (derived parameter)

74. ADMBA - number of administrators having better than a B.A. degree

75. ADBAR - (ADMBA/ADMNU)/.83--83 per cent is the national average of administrators having better than a B.A. degree

76. EDADC - the average number of educational courses taken by the administrator

77. EDADR - ADADC/46--46 is national average of educational courses taken by administration

78. ADMJK - average score made by the administration on the National Teacher's Examination, supervisory portion

79. ADJKA - ADMJK/500--500 is the national average score of administrators on the National Teacher's Examination

80. PQADM - professional qualifications of the school's administrators (derived parameter)

81. AVADM - average number of years experience that the administration has at this school

82. AVADR - AVADM/3.5--3.5 is the national average for experience of administration at one school

83. AVTAD - average number of years of teaching experience of administration

84. AVTAR - AVTAD/11--11 is national average of teaching experience of administrators

85. ADMEX - administrative experience (derived parameters)

86. AAAFA - average age of the administration at first administrative appointment

87. AAAFR - AAAFA/30--30 is assumed to be an adequate age for the first administrative appointment

88. TTORT - teacher turnover rate

89. TTPTA - percentage of teachers teaching in their properly trained area

90. TTPTR - TTPTA/.92--92 per cent is the national average of teachers teaching in appropriate area

91. ADMOA - administration's manifestations of ability (derived parameter)

92. ADMSA - average administrator salary

93. ADMSR - ADMSA/12,500--$12,500 is national average administrative salary

94. CSADM - competence of the school's administrators (derived parameter)

95. TOEXP - total amount of all expenditures of the school

96. EXPST - (TOEXP/STDNU)/450--$450 is national average expenditures per school per student

97. TEANU - total number of teachers in the school

98. TNADM - (TEANU/ADMNU).17--17 teachers per administrator is national average

99. ADANU - total number of administrative aids, e.g., secretaries, bookkeepers, etc.

100. ADADN - (ADANU/ADMNU)/4--4 aids per administrator is national average

101. EFADM - the effectiveness of the school's administration (derived perameter)

102. SCSNU - the total number of school counselors, e.g., speech therapist, remedial reading, guidance counselors, psychologists, social workers, and psychiatric workers

103. TADNU - total number of teaching aids

104. SSTNU - SCSNU + TADNU + TEANU + ADMNU + ADANU

105. SSSNU - SSTNU/STDNU

106. TEABA - number of teachers having at least a B.A. degree

107. TEABR - (TEABA/TEANU).88--88 per cent is national average of teachers having at least a B.A. degree

108. TEAMA - number of teachers having a masters or doctorate degree

109. TEAMR - (TEAMA/TEANU)/.25--25 per cent is national average of teachers having a masters or doctorate degree

110. TEANS - number of teachers belonging to National Teacher's Association at state level

111. TEANR - (TEANS/TEANU)/.92--92 per cent is national average of teachers belonging to National Teacher's Association at state level

112. TEANF - number of teachers belonging to National Teacher's Association at federal level

113. TEANZ - (TEANF/TEANU)/.67--67 per cent is national average of teachers belonging to National Teacher's Association at federal level.

114. TEATI - number of teachers attending N.S.F., N.D.E.A., or E.S.E.A. training institutes

115. TEATR - (TEATI/TEANU)/.06 or .15--6 per cent is national average for elementary school teachers, while 15 per cent is national average for high school teachers attending training institutes

116. TEAYR - average number of years teaching experience per teacher

117. TEAEX - TEAYR/14--14 is national average of teaching experience

118. TEAPR - teacher professionalism (derived parameter)

119. DIRCM - direction of communication between teacher and student (rated variable)

120. DISLE - lecture versus discussion presentation of material by teacher (rated variable)

121. SPTNU - average number of students in each classroom

122. OPCOM - openness of teacher communication in classroom (derived parameter)

123. APEAS - average teacher salary

124. ATESN - ATEAS/7.000--$7,000 is national average for teacher's salary

125. TJOBK - teacher job knowledge measured by the national teacher's examination scores

126. TJBKA - TJOBK/500--500 is national average teacher's score on National Teacher's Examination

127. TAAGE - average teacher age in the school

128. TAGER - TAAGE/40--40 is the national average age of teachers

129. TUINM - teacher usage of innovative instructional media (rated variable)

130. TEACO - teacher competence in the school (derived parameter)

131. SSNNU - SSSNU/.05--.05 is national average of professional staff per hundred students

132. ADESS - adequacy of the school staff (derived parameter)

133. STSAS - staff salary average of the entire school

134. STSAR - STSAS.7,300--$7,300 is assumed to be an adequate staff salary

135. SFMOR - staff morale (derived parameter)

136. COINS - the school's institutional climate (derived parameter)

137. TWKLD - (STDNU/TEANU)/140--140 students per teacher is approximately the national average

138. TEAF - teacher effectuality (derived parameter)

139. VEENS - the capital evaluation of non-educational equipment in the school

140. VNEES - (VEENS.STDNU)/100--$100 per student is assumed to be an adequate index of non-educational equipment

141. GYMSS - (ARGYM/STDNU)/12--12 square feet per student is assumed to be an adequate gym area

142. ADUSS - (AUDAR.STDNU)/16--16 square feet per student is assumed to be an adequate auditorium area

143. EXCST - the number of extra-curricular staff employed

144. STDIN - number of student organizations in the extra-curricular activities (one organization per 64 students is assumed to be adequate)

145. STDOS - STDIN/STDNU

146. EXCSS - (STDNU/100)/EXCST

147. OPAPR - the acres of outdoor play areas including athletic fields

148. OPAPS - (OPAPE/STDNU)/5 acres per 400 students--this is assumed to be an adequate index of play areas

149. ADEEC - the adequacy of extra-curricular school activities (derived parameter)

150. ASCLD - the square footage of science laboriatories

151. ASCLA - (ASCLB/STDNU)/63--63 is the national average for square footage per student in science laboratories

152. SCLAB - the number of science laboratories

153. SCLAN - SCLAB/(STDNU/500) one laboratory per 500 students is assumed to be an adequate index

154. SMLCO - the number of science, mathematics, and logic courses presently taught

155. SMLCN - SMLCO/(STDNU/100)

156. SMLRP - number of science, mathematics, and logic courses required per student (nine courses assumed to be an adequate figure)

157. SMLTS - number of science, mathematic, and logic teachers

158. SMLTP - SMLTS/(STDNU/150) one teacher per 150 students is assumed to be an adequate ratio

159. SCOCT - the school's emphasis on critical thinking skill development in students (derived parameter)

160. ELEPP - total number of elective courses

161. ELEPS - ELEPP/(STDNU/100)

162. BOFEP - the breadth of the school curriculum program (tally point 1 for each of the following programs which the school has: vocational, preparatory, commercial, general, art, music, industrial arts, agriculture, three foreign languages, and guidance program)

163. SEOCO - the school's emphasis on cognitive openness development in students (derived parameter)

164. SSBPP - total number of courses in the behavioral and social sciences

165. BSSPP - SSBPP/(STDNU/100)

166. BSSRS - number of behavioral and social science courses required per student (6 is assumed to be an adequate figure)

167. TBSSP - number of behavioral and social science teachers

168. TBSSS - TBSSP/(STDNU/150) one teacher per 150 students is assumed to be an adequate ratio

169. SEOSO - the school's emphasis on socialization skill development in students (derived parameter)

170. RWSPP - number of reading, writing, and speaking courses

171. RWSPS - RWSPP/(STDNU/100)

172. RRWSS - the number of reading, writing, and speaking courses required per pupil (6 courses is assumed to be adequate)

173. TRWSP - number of teachers in reading, writing, and speaking courses

174. TRWSS - TRWSP/(STDNU/150) one teacher per 150 students is assumed to be an adequate ratio

175. SEOCM - the school's emphasis on communication skill development in students (derived parameter)

176. VLMPS - the number of vocational courses in the school

177. VLMPP - VLMPS/(STDNU/1000) one laboratory per 1000 students is assumed to be adequate

178. VSMPS - the number of vocational, art, shop, home economics, industrial arts, commercial education, and agriculture courses

179. VCMPP - VCMPS.(STDNU/200) one course per 200 students is adequate

180. VCRPP - the number of vocational, art, shop, home economics, industrial arts, commercial education, and agriculture courses required per student (3 courses is assumed to be adequate)

181. VCTPS - the number of vocational, art, shop, home economics, industrial arts, commercial education, and educational teachers

182. VCTPP - VCTPS/(STDNU/500) one teacher per 500 students is assumed to be an adequate ratio

183. SEOPR - the school's emphasis on performance skill development in students (derived parameter)

184. CODE - the school's level of education (-1 = elementary; 0 = junior high; 1 = high school)

185. CODEA - the number of grades in the school

186. CODEB - STDNU/CODEA

187. CPVLE - capital evaluation dollar value of science laboratory equipment

188. CPVLS - (CPVLE/STDNU)60--$60 is assumed to be an adequate amount of money for laboratory equipment per student

189. BOOKS - the number of books on science, mathematics, or logic

190. BOOKR - (BOOKS/BOOKL).30--30 per cent is assumed to be an adequate index

191. STDIL - the average number of students per science laboratory class

192. VTNUC - the number of vocational counselors

193. VTNZP - VTNUC/(STDNU/500)

194. VTVAT - capital evaluation dollar value of fixed vocational equipment

195. VTVAZ - (VTVAT/STDNU)/15 - $15 is assumed to be an adequate amount of money in vocational equipment per student

196. EFFIN - the school's instructional effectuality (derived parameter)

197. EDEFF - the school's educational effectuality (derived parameter)

Appendix B

Equations Defining Relationship

in the School Model

Equation 1

$$COMSP = A_1(TAXNO) + A_2(RVOTE) + A_3(RTAX) + A_4(DEBTN) + A_5(PTAST)$$

Equation 2

$$SPAAD = \frac{GROED}{120(STDNU)} \times \frac{SITE}{10+\ STDNU/100}$$

- 10+ STDNU/100 - elementary school
- 15+ STDNU/100 - junior high
- 30+ STDNU/100 - high school

Equation 3

$$ADEMO = A_6(CPEVS) + A_7(SMAIN) + A_8(OPERS)$$

Equation 4

$$ADEIE = A_9(EXIMC) + A_{10}(DINSN) + A_{11}(SLIBB)$$

Equation 5

$$ADESF = A_{12}\left(1 + \frac{BLDIN}{6.0}\right) + A_{13}\ (SPAAD) + A_{14}(0.70 - |DESEF - 0.70|)$$

$$+ A_{15}(ADEMO) + A_{16}\ (ADEIE)$$

Equation 6

$$PROSC = A_{17}(EXPCU) + A_{18}(EXCLD) + A_{19}(CMOVD) + A_{20}(CRROG) = A_{21}(SINDV)$$

Equation 7

$$PROGS = A_{22}(PROSC) + A_{23}(EXABG) + A_{24}(EXONG) + A_{25}(EXOAC)$$

$$+ A_{26}(EXOTT) + A_{27}(ADESF)$$

Equation 8

$$ADEAR = A_{28}(DTADN) + A_{29}(TADIR)$$

Equation 9

$$PQADM = A_{30}(ADBAR) + A_{31}(EDADR) + A_{32}(ADJKA)$$

Equation 10

$$ADMEX = A_{33}{}^{(1 + AVADR)} + A_{34}(1 + AVADR)$$

Equation 11

$$ADMOA = A_{35}(AAAFR) + A_{36}(TTPTR) + A_{37}(PROSC) + A_{38}(1 + |\frac{TTORT-11.0}{10.0}|)$$

Equation 12

$$CSADM = A_{39}(ADMOA) + A_{40}(ADMEX) + A_{41}(ADMSR) + A_{42}(PQADM) + A_{43}(ADEAR)$$

Equation 13

$$EFADM = A_{44}(CSADM) + A_{45}(ADADN) + A_{46}(TNADM) + A_{47}(EXPST) + A_{48}(COMSP)$$

Equation 14

$$TEAPR = A_{49}(TEABR) + A_{50}(TEAMR) + A_{51}(TEANR) + A_{52}(TEANZ) + A_{53}(TEATR) + A_{54}{}^{(1 + TEAEX)}$$

Equation 15

$$OPCOM = ([0.5 - |DIRCM - 0.5|]/0.5) \times ([0.8 - |DISLE - 0.8|]/0.8) \times (\frac{24.0}{SPTNU})$$

Equation 16

$$TEACO = A_{55}(OPCOM) + A_{56}(ATESN) + A_{57}(TJBKA) + A_{58}(TEAPR) + A_{59}(ADEIE) + A_{60}(TUINM) + A_{61}{}^{(1 + TAGER)}$$

Equation 17

$$ADESS = A_{62}(TEACO) + A_{63}(EFDAM) + A_{64}(SSNNU)$$

Equation 18

$$SFMOR = A_{65}(ADESS) + A_{66}(ADESF) + A_{67}(STSAR) + A_{68}([400 - |CODEB - 400|]/400) = A_{69}(COMSP)$$

Equation 19

$$CLINS = A_{70}(SFMOR) + A_{71}(SINDV) + A_{72}(PROGS)$$

Equation 20

$$TEAEF = A_{73}(CLINS) + A_{74}(TEACO) + A_{75}(ADESF) + A_{76}(1 + TWKLD)$$

Equation 21

$$ADEEC = A_{77}(VNEES) + A_{78}(GYMSS) + A_{79}(STDOS) + A_{80}(ADUSS) + A_{81}(EXCSS) + A_{82}(OPAPS)$$

Equation 22

$$SEOCT = A_{83}(ASCLA) + A_{84}(SCLAN) + A_{85}(SMLCN) + A_{86}(SMLTP) + A_{87}(SPTNU) + A_{88}(BOOKR) + A_{89}(TWKLD) + A_{90}(DINST) + A_{91}(SMLRP) + A_{92}(CPVLS)$$

Equation 23

$$SEOSO = A_{93}(BSSPP) + A_{94}(BSSRS) + A_{95}(TBSSS) + A_{96}(BOFEP) + A_{97}(COMSP) + A_{98}(ADEEC) + A_{99}(SCSNU) + A_{100}(SPTNU) + A_{101}([400 - |CODEB - 400|]/400)$$

Equation 24

$$SEOCM = A_{102}(RWSPS) + A_{103}(RRWSS) + A_{104}(TRWSS) + A_{105}(ADEEC) + A_{106}(SPTNU)$$

Equation 25

$$SEOPR = A_{107}(VLNPP) + A_{108}(VCNPP) + A_{109}(VCRPP) + A_{110}(VCTPP) + A_{111}(VTNZP) + A_{112}(VTVAZ) + A_{113}(COMSP)$$

Equation 26

$$SEOCO = A_{114}(ELEPS) + A_{115}(BOFEP) + A_{116}(SEOCT) + A_{117}([400 - |CODEB - 400|]/400) + A_{118}(OPCOM) + A_{119}(PROGS)$$

Equations 27 - 31

$$EFICT = (TEAEF)\ (SEOCT)$$

$$EFISO = (TEAEF)\ (SEOSO)$$

$$EFICM = (TEAEF)\ (SEOCM)$$

$$EFIPR = (TEAEF)\ (SEOPR)$$

$$EFICO = (TEAEF)\ (SEOCO)$$

Equations 32 - 36

$$EDECT = A_{120}(ADEED) + A_{121}(EFICT)$$

$$EDESO = A_{120}(ADEEC) + A_{121}(EFISO)$$

$$EDECM = A_{120}(ADEEC) + A_{121}(EFICM)$$

$$EDEPR = A_{120}(ADEEC) + A_{121}(EFIPR)$$

$$EDECO = A_{120}(ADEEC) + A_{121}(EFICO)$$

Appendix C

Weights for Equations Defining Relationships in the School Model

Equation	Variable Code Name	Weight	Equation	Variable Code Name	Weight
1	RVOTE	.2	7	EXOAC	.2
1	RTAX	.3	7	EXOTT	.2
1	DEBT	.3	7	ADESF	.2
1	PTAST	.1	8	DTADN	.5
1	TAXNO	.1	8	TADIR	.5
3	CPEVS	.8	9	ADBAR	.4
3	SMAIN	.1	9	EDADR	.2
3	OPERS	.1	9	ADJKA	.4
4	EXIMC	.1	10	AVTAR	.5
4	DINSN	.6	10	AVADR	.5
4	SLIBB	.3	11	AAAFR	.1
5	BLDIN	.1	11	TTPTR	.2
5	SPAAD	.3	11	PROSC	.5
5	DESEF	.1	11	TTORT	.2
5	ADEMO	.2	12	ADMOA	.3
5	ADEIE	.3	12	ADMEX	.1
6	EXPCU	.2	12	ADMSR	.1
6	EXCLD	.1	12	PQADM	.3
6	CMOVD	.1	12	ADEAR	.2
6	CRROG	.1	13	CSADM	.4
6	SINDV	.5	13	ADADN	.1
7	PROSC	.3	13	TNADM	.1
7	EXABG	.1	13	EXPST	.3
7	EXONG	.1	13	COMSP	.1

Equation	Variable Code Name	Weight	Equation	Variable Code Name	Weight
14	TEABR	.2	19	PROGS	.4
14	TEAMR	.3	20	CLINS	.15
14	TEANR	.1	20	TEACO	.4
14	TEANZ	.1	20	ADESF	.15
14	TEATR	.2	20	TWKLD	.3
14	TEAEX	.1	21	VNEES	.3
16	OPCOM	.2	21	GYMSS	.05
16	ATESN	.05	21	STDOS	.3
16	TJBKA	.2	21	ADUSS	.05
16	TEAPR	.3	21	EXCSS	.2
16	ADEIE	.1	21	OPAPS	.1
16	TUINM	.1	22	ASCLA	.1
16	TAGER	.05	22	SCLAN	.1
17	TEACO	.3	22	SMLCN	.1
17	EFADM	.3	22	SMLTP	.1
17	SSNNU	.4	22	SPTNU	.1
18	ADESS	.3	22	BOOKR	.1
18	ADESF	.3	22	TWKLD	.1
18	STSAR	.2	22	DINSN	.1
18	CODEB	.1	22	SMLRP	.1
18	COMSP	.1	22	CPVLS	.1
19	SFMOR	.3	23	BSSPP	.1
19	SINDV	.3	23	BSSRS	.1

Equation	Variable Code Name	Weight
23	TBSSS	.1
23	BOFEP	.1
23	COMSP	.1
23	ADEEC	.15
23	SCSNU	.1
23	SPTNU	.1
23	CODEB	.15
24	RWSPS	.2
24	RRWSS	.2
24	TRWSS	.2
24	ADEEC	.2
24	SPTNU	.2
25	VLNPP	.2
25	VCNPP	.15
25	VCRPP	.1
25	VCTPP	.15
25	VTNZP	.05
25	VTVAZ	.3
25	COMSP	.05
26	ELEPS	.1
26	BOFEP	.2
26	SEOCT	.3
26	CODEB	.1
26	OPCOM	.1
26	PROGS	.2
32-36	ADEEC	.2
32	EFICT	.8
33.	EFICO	.8
34	EFICM	.8
35	EFIPR	.8
36	EFISO	.8

Appendix D

Computer Program for the School Model

```
    DIMENSION A(121), TITLE (20), X1(50), Y1(50), Y2(50), Y3(50),
   1Y4(50, Y5(50)
    READ(1,1) TITLE
  1 FORMAT(20A4)
    PRINT 1, TITLE
    READ(1,101)STDNU,TAXUS,TAXNT,PVOTE,TVOTE,STTAX,PDTAX,DEBT,STDNA
   1PTAMB
101 FORMAT(F12.1)
    READ(1,102)ELEPP,TWKLD,ADMSA,BLDIN
102 FORMAT(F8.1)
    READ(1,103)STSAS,CODEA,SCSNU,TADNU,STITE,CODE
103 FORMAT(2F7.1)
    READ(1,104)RWSPP,RRWSS,TRWSP,DIRCM,DISLE,SPTNU,TOEXP,TEANU,ADANU,
   1ADMBA,EDADC,ADMJK,DTADC,TADIL,ADMNU,EXIMC,DINST,BOOKL,DMAIN,OPERA
   1CPEVL,FLOOR,EXTRA,PLAY
104 FORMAT(3F5.1/3F5.1/F9.1,2F6.1/2F5.1,F7.1/3F5./F5.1,2F9.1/3F9.1/
   13F9.1)
    READ(1,105)SSBPP,BSSRS,TBSSP,BOFEP,VEENS,EXCST,STDIN,OPAPR,ATFAS,
   1TJOBK,TAAGE,TUINM,EXABG,EXONG,EXOAC,EXOTT
105 FORMAT(4F5.1/F9.1,3F6.1/4F7.1/4F5.1)
    READ(1,106)AVADM,AVTAD,AAAFA,TTORT,TTPTA,EXPCU,EXCLD,CMOVD,CRROG,
   1DVINS
106 FORMAT(F5.1,4F6.2/4F5.1,F9.1)
    READ(1,107)TEABA,TEAMA,TEANS,TEANF,TEATI,TEAYR,AUDAR,CAFET,ABAND,
   1ALIBY,ARGYM,ABSPC
107 FORMAT(6F6.1/2F9.1,2F8.1,2F9.1)
    READ(1,108)CLASS,STUDY,ARTSP,HOME,SHOP,COMED,ABSPA
108 FORMAT(7F8.1)
    READ(1,109) VLNPS, VCNPS,VCRPP,VCTPS,VTNUC,VTVAT,ASCLB,SCLAB,
   1SMLCO,SMLRP,SMLTS,CPVLE,BOOKS,STDIL
109 FORMAT(5F5.1,F10.1/F7.1,F5.1,F6.1,F5.1,F6.1,F9.1,F8.1,F6.1)
110 FORMAT (F7.2)
    DO 111 K=1,121
111 READ (1,110) A(K)
    TAXNO=(TAXUS/TAXNT)/0.05
    RVOTE=(PVOTE/TVOTE?/0.50
    RTAX=PDTAX/STTAX
    DEBTN=(DEBT/STDNA)/400.0
    PTAST=PTAMB/STDNU
    COMSP=A(1)*TAXNO+A(2)*R )TE+A(3)*RTAX+A(4)*DEBTN+A(5)*PTAST
    ABARE=ARTSP+HOME+SHOP+COMED+ABSPA
    STRUC=CLASS+STUDY
    AUXSP=AUDAR+CAFET+ABAND+ALIBY+ARGYM+ABSPC
    EDNET=STRUC+ABARE+AUXSP
    GROED=FLOOR+EXTRA+PLAY
    DESEF=EDNET/GROED
    IF(CODE-0.0) 50,50,60
 40 SPAAD=(GROED/(120.0*STDNU) )*SITE/(10.0+(STDNU/100.0))
 50 SPAAD=(GROED/(120.0*STDNU) )*SITE/(20.0+(STDNU/100.0))
 60 SPAAD=(GROED/(120.0*STDNU) )*SITE/(30.0+(STDNU/100.0))
```

```
 OPERS=(OPERA/STDNU)/40.0
 SMAIN=(DMAIN/STDNU)/13.0
 CPEVS=(CPEVL/STDNU)/1000.0
 ADEMO+A(6)*CPEVS+A(7)*SMAIN+A(8)*OPERS
 DINSN=(DINST/STDNU)/95.0
 SLIBB=(BOOKL/STDNU)/6.0
 ADEIE=A(9)*EXIMC+A(10)*DINSN+A(11)*SLIBB
 ADESF=A(12)**(1.0+(BLDIN/6.0))+A(13)*SPAAD+A(14)*((0.7-ABS(DESEF-
10.7))/9.7)+A(15)*ADEMO+A(16)*ADEIE
 SINDV=(DVINS/STDNU)/300.0
 PROSC=A(17)*EXPCU+A(18)*EXCLD+A(19)*CMOVD+A(20)+CRROG+A(21)*SINDV
 PROGS=A(22)*PROSC+A(23)*EXABG+A(24)*EXONG+A(25)*EXOAC+A(26)*EXOTT
1+A(27)*ADESF
 DTADN=DTADC/2.0
 TADIR=(TADIL/ADMNU)/3.0
 ADEAR=A(38)*DTADN+A(29)*TADIR
 ADBAR=(ADMBA/ADMNU)/9.83
 EDADR=EDADC/46.0
 ADJKA=ADMJK/500.0
 PQADM=A(30)*ADBAR+A(31)*EDADR+A(32)*ADJKA
 AVADR=AVADM/5.3
 AVTAR=AVTAD/11.0
 ADMEX=A(33)**(AVTAR)+A(34)**(AVADR)
 AAAFR=AAAFA/30.0
 TTPTR=TTPTA/0.92
 ADMOA=A(35)*AAAFR+A(36)*TTPTR+A(37)*PROSC+A(38)**(1.0+ABS((TTORT-
111.0)/10.0))
 ADMSR=ADMSA/12500.0
 CSADM=A(39)*ADMOA+A(40)*ADMEX+A(41)+ADMSR+A(42)*PQADM+A(43)*ADEAR
 EXPST=(TOEXP/STDNU)/450.0
 TNADM=(TEANU/ADMNU)/17.0
 ADADN=(ADANU/ADMNU)/4.0
 EFADM=A(44)*CSADM+A(45)*ADADN+A(46)*TNADM+A(47)*EXPST+A(48)*COMSP
 SSSNU=(SCSNU+TADNU+TEANU+ADMNU+ADANU)/STDNU
 TEABR=(TEABA/TEANU)/0.88
 TEAMR=(TEAMA/TEANU)/0.25
 TEANR=(TEANS/TEANU)/0.92
 TEANZ=(TEANF/TEANU)/0.67
 IF(CODE-0.0) 70,80,90
70 TEATR=(TEATI/TEANU)/0.06
80 TEATR=(TEATI/TEANU)/0.10
90 TEATR=(TEATI/TEANU)/0.15
 TEAFX=TEAYR/14.0
 TEAPR=A(49)*TEABR+A(50)*TEAMR+A(51)*TEANR+A(52)*TEANX+A(53)*TEATR
1+A(54)**(TEAEX)
 OPCOM=((0.5-ABS(DIRCM-0.5))/0.5)*((0.8-ABS(DISLE-0.8))/0.8)*(24.0
1/SPTNU)
 ATESN=ATEAS/7000.0
 TJBKA=TJOBK/500.0
 TAGER=TAAGE/40.0
```

```
 TEACO=A(55)*OPCOM+A(56)*ATESN+A(57)*TJBKA+A(58)*TEAPR+A(59)*ADEIE
1+A(60)*TUINM+A(61)**(TAGER)
 SSNNU=SSSNU/0.054
 ADESS=A(62)*TEACO+A(63)*EFADM+A(64)*SSNNU
 STSAR=(16.0*ATEAS+ADMSA)/17.0
 STSAR=STSAR/STSAS
 CODEB=STDNU/CODEA
 SFMOR=A(65)*ADESS+A(66)*ADESF+A(67)*STSAR+A(68)*((500.0-ABS(CODEB
1-400.0))/400.0)+A(69)*COMSP
 CLINS=A(70)*SFMOR+A(71)*SINDV+A(72)*PROGS
 TWKLR=TWKLD/140.0
 TEAEF=A(73)*CLINS+A(74)*TEACO+A(75)*ADESF+A(76)**(TWKLR)
 GYMSS=(ARGYM/STDNU)/12.0
 VNEES=(VEENS/STDNU)/100.0
 ADUSS=(AUDAR/STDNU)/15.0
 STDOS=STDIN/(STDNU/100.0)
 EXCSS=EXCST/(STDNU/100.0)
 OPAPS=OPAPR/((STDNU*5.0)/400.0)
 ADEEC=A(77)*VNEES+A(78)*GYMSS+A(79)*STDOS+A(80)*ADUSS+A(81)*EXCSS
1+A(82)*OPAPS
 BOOKR=(B((KS/BOOKL)/0.30
 ASCLA=(ASCLB/STDIL)/63.0
 SMLRR=SMLRP/9.0
 SCLAN=SCLAB/(STDNU/500.0)
 SMLCN=SMLCO/(STDNU/100.0)
 CPVLS=(CPVLE/STDNU)/60.0
 SMLTP=SMLTS/(STDNU/150.0)
 SEOCT=A(83)*ASCLA+A(84)*SCLAN+A(85)*SMLCN+A(86)*SMLTP+A(87)*(24.0
1/SPTNU) +A(88)*BOOKR+A(89)**(TEKLR)+A(90)*DINSN+A(91)*SMLRR+A(92)*
1CPVLS
 BSSRR=BSSRS/6.0
 TBSSR=TBSSP/(STDNU/200.0)
 BSSPP=SSBPP/(STDNU/100.0)
 SEDSO=A(93)*BSSPP+A(94)*BSSRR+A(95)*TBSSR+A(96)*BOFEP+A(97)*COMSP
1+A(98)*ADEEC+A(99)*(SCSNU/(STDNU/1600.0))+A(100)*(24.0/SPTNU)+A(10
11)*((400.0-ABS(CODEB-400.0))/400.0)
 RRWSR=RRWSS/6.0
 RWSPS=RWSPP/(STDNU/100.0)
 TRWSS=TRWSP/(STDNU/150.0)
 SEOCM=A(102)*RWSPS+A(103)*RRWSR+A(104)*TRWSS+A(105)*ADEEC+A(106)*
1(24.0/SPTNU)
 VLNPP=VLNPS/(STDNU/1000.0)
 VCNPP=VCNPS/(STDNU/200.0)
 VCTPP=VCTPS/(STDNU/150.0)
 VCRPR=VCRPP/3.0
 VTNZP=VTNUC/(STDNU/500.0)
 VTVAZ=(VTVAT/STDNU)/15.0
 SEOPR=A(107)*VLNPP+A(108)*VCNPP+A(109)*VCRPR+A(110)*VCTPP+A(111)
1*VTNZP+A(112)*VTVAZ+A(113)*COMSP
 ELEPS=ELEPP/(STDNU/50.0)
```

```
 SEOCO=A(114)*ELEPS+A(115)*BOFEP+A(116)*SEOCT+A(117)*((400.0-ABS(
1CODEB-400.0))/400.0)+A(118)*OPCOM+A(119)*PROGS
 EFICT=TEAEF*SEOCT
 EFICO=TEAEF+SEOCO
 EFIPR=TEAEF*SEOPR
 EFICM=TEAEF*SEOCM
 EFISO=TEAEF*SEOSO
 EDECO=(A(120)*ADEEC+A(121)*EFICO)*100.0
 EDECT=(A(120)*ADEEC+A(121)*EFICT)*100.0
 EDECM=(A(120)*ADEEC+A(121)*EFICM)*100.0
 EDEPR=A(A120)*ADEEC+A(121)*EFIPR)*100.0
 EDESO=(A(120)*ADEEC+A(121)*EFISO)*100.0
 ADESF=ADESF*100.
 PROGS=PROGS*100.
 EFADM=EFADM*100.
 TEACO=TEACO*100.
 ADEEC=ADEEC*100.
 SFMOR=SFMOR*100.
 ADESS=ADESS*100.
 CLINS=CLINS*100.
 TEAEF=TEAEF*100.
 SEOCT=SEOCT*100.
 SEOCO=SEOCO*100.
 SEOCM=SEOCM*100.
 SEOSO=SEOSO*100.
 SEOPR=SEOPR*100.
   PRINT 2
 2 FORMAT(30HOADEQUACY OF SCHOOL FACILITIES)
   PRINT 3, ADESF
 3 FORMAT (14X,F10.5)
   PRINT 4
 4 FORMAT (30HOPROGRESSIVENESS OF THE SCHOOL)
   PRINT 3,PROGS
   PRINT 5
 5 FORMAT(43HOEFFECTIVENESS OF THE SCHOOL ADMINISTRATION)
   PRINT 3, EFADM
   PRINT 6
 6 FORMAT(33HOTEACHER COMPETENCE IN THE SCHOOL)
   PRINT 3, TEACO
   PRINT 7
 7 FORMAT(29HOADEQUACY OF THE SCHOOL STAFF)
   PRINT 3, ADESS
   PRINT 8
 8 FORMAT(27HOSTAFF MORALE IN THE SCHOOL)
   PRINT 3, SFMOR
   PRINT 9
 9 FORMAT(36HOINSTITUTIONAL CLIMATE OF THE SCHOOL)
   PRINT 3, CLINS
   PRINT 10
10 FORMAT(35HOTEACHER EFFECTUALITY IN THE SCHOOL)
   PRINT 3, TEAEF
```

```
      PRINT 11
   11 FORMAT(51HOADEQUACY OF THE SCHOOL EXTRA-CURRICULAR ACTIVITIES)
      PRINT 3, ADEEC
      PRINT 12
   12 FORMAT(52HOSCHOOL'S EMPHASIS ON COGNITIVE OPENNESS DEVELOPMENT)
      PRINT 3, SEOCO
      PRINT 13
   13 FORMAT(55HOSCHOOL EMPHASIS ON CRITICAL THINKING SKILL DEVELOPMENT)
      PRINT 3, SEOCT
      PRINT 14
   14 FORMAT(53HOSCHOOL'S EMPHASIS ON SOCIALIZATION SKILL DEVELOPMENT)
      PRINT 3, SEOSO
      PRINT 15
   15 FORMAT(53HOSCHOOL'S EMPHASIS ON COMMUNICATION SKILL DEVELOPMENT)
      PRINT 3, SEOCM
      PRINT 16
   16 FORMAT(51HOSCHOOL'S EMPHASIS ON PERFORMANCE SKILL DEVELOPMENT)
      PRINT 3, SEOPR
      PRINT 17
   17 FORMAT(48HOEDUCATIONAL EFFECTUALITY FOR COGNITIVE OPENNESS)
      PRINT 3, EDECO
      PRINT 18
   18 FORMAT(47HOEDUCATIONAL EFFECTUALITY FOR CRITICAL THINKING)
      PRINT 3, EDECT
      PRINT 19
   19 FORMAT(43HOEDUCATIONAL EFFECTUALITY FOR SOCIALIZATION)
      PRINT 3, EDESO
      PRINT 20
   20 FORMAT(43HOEDUCATIONAL EFFECTUALITY FOR COMMUNICATION)
      PRINT 3, EDECM
      PRINT 21
   21 FORMAT(41HOEDUCATIONAL EFFECTUALITY FOR PERFORMANCE)
      PRINT 3, EDEPR
      CALL EXIT
      END
```

Appendix E

Data for Typical, Poor, and Outstanding Schools Simulations

(Fundamental Parameter Values)

Variable Name	Typical School	Poor School	Good School
ADMNU	4	4	6
EXIMC	1	0	1
DINST	152000	122000	170000
BOOKL	9600	7100	12000
DMAIN	20800	12000	32000
OPERA	64000	53000	75000
CPEVL	1600000	1200000	2000000
FLOOR	90000	60000	120000
EXTRA	10000	5000	20000
PLAY	92000	67000	120000
SSBPP	16	12	21
BSSRS	6	3	9
TBSSP	8	4	12
BOFEP	1	0	1
VEENS	160000	130000	190000
EXCST	16	12	20
STDIN	16	12	20
OPAPR	20	15	25
ATEAS	7000	5000	9000
TJOBK	500	300	700
TAAGE	40	50	30
TUINM	1	.2	1
EXABG	1	0	1
EXONG	1	0	1
EXOAC	1	0	1
EXOTT	1	0	1
AVADM	5.3	2.7	5.3
AVTAD	11	5.5	11
AAAFA	30	15	25
TTORT	11	20	11
TTPTA	.92	.1	1
EXPCU	1	0	1
EXCLD	1	0	1
CMOVD	1	0	1
CRROG	1	0	1
DVINS	480000	320000	620000
STDNU	1600	3000	1600
TAXUS	36000	20000	50000
TAXNT	720000	400000	1500000
PVOTE	5000	2000	9000
TVOTE	10000	10000	10000
STTAX	10000000	10000000	10000000
PDTAX	10000000	50000000	15000000
DEBT	2000000	1000000	5000000
STDNA	5000	5000	5000
PTAMB	1600	800	2500
ELEPP	32	16	50
TWKLD	140	170	100

Variable Name	Typical School	Poor School	Good School
ADMSA	12500	9000	15000
BLDIN	0	6	0
STSAS	7300	5500	9500
CODEA	4	4	4
SCSNU	1	.5	3
TADNU	0	0	10
SITE	46	32	60
CODE	1	1	1
RWSPP	16	10	30
RRWSS	6	3	9
TRWSP	10.66	6	13
DIRCM	.5	.8	.5
DISLE	.8	.2	.8
SPTNU	24	36	15
TOEXP	720000	550000	900000
TEANU	66	53	80
ADANU	16	12	20
ADMBA	3.32	1.7	0
EDADC	46	31	58
ADMJK	500	300	700
DTADC	2	1	4
TADIL	12	8	18
TEABA	58	45	65
TEAMA	16	10	25
TEANS	61	50	66
TEANF	44	33	55
TEATI	10	5	20
TEAYR	14	20	14
AUDAR	20000	10000	30000
CAFET	10000	5000	15000
ABAND	1000	500	1500
ALIBY	4000	2000	6000
ARGYM	21900	12000	30000
ABSPC	3000	1000	5000
CLASS	63000	50000	80000
STUDY	2000	1000	4000
ARTSP	1000	500	3000
HOME	1000	500	3000
SHOP	1000	500	3000
COMED	1000	500	3000
ABSPA	4500	1500	6000
VLNPS	1.6	.5	3
VCNPS	8	7.8	9.9
VCRPP	3	1	6
VCTPS	10.66	7.3	13
VTNUC	3.2	1	5

Variable Name	Typical School	Poor School	Good School
VTVAT	24000	12000	30000
ASCLB	1500	1000	2000
SCLAB	3	1	6
SMLCO	16	10	24
SMLRP	9	6	12
SMLTS	11	9	13
CPVLE	96000	66000	120000
BOOKS	2880	1200	4000
STDIL	24	36	24